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Enregistrement des procédures chirurgicales crâniennes et rachidiennes, et analyse des « workflows » pour l'étude du processus chirurgical

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Enregistrement des procédures chirurgicales crâniennes et rachidiennes, et analyse des « workflows » pour l'étude du processus chirurgical.

Recording of cranial and spinal surgical procedures, and analysis of workflows for study of the surgical processes.

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INTRODUCTION

Introduction

Analysing the surgical process, understanding the learning of the necessary gestures, how best to prepare them and carry them out, is an ambitious project. For many years the laboratories of the University of Rennes IDM UPRES EA 3192, VisAGeS U746 and MediCIS U1099 LTSI have been carrying out a number of studies with the aim of defining the tools and strategies which can facilitate the process of preparing for surgical procedures[23,24] and also of analysing and understanding the factors involved in applying the procedures.[25,26,39,50]

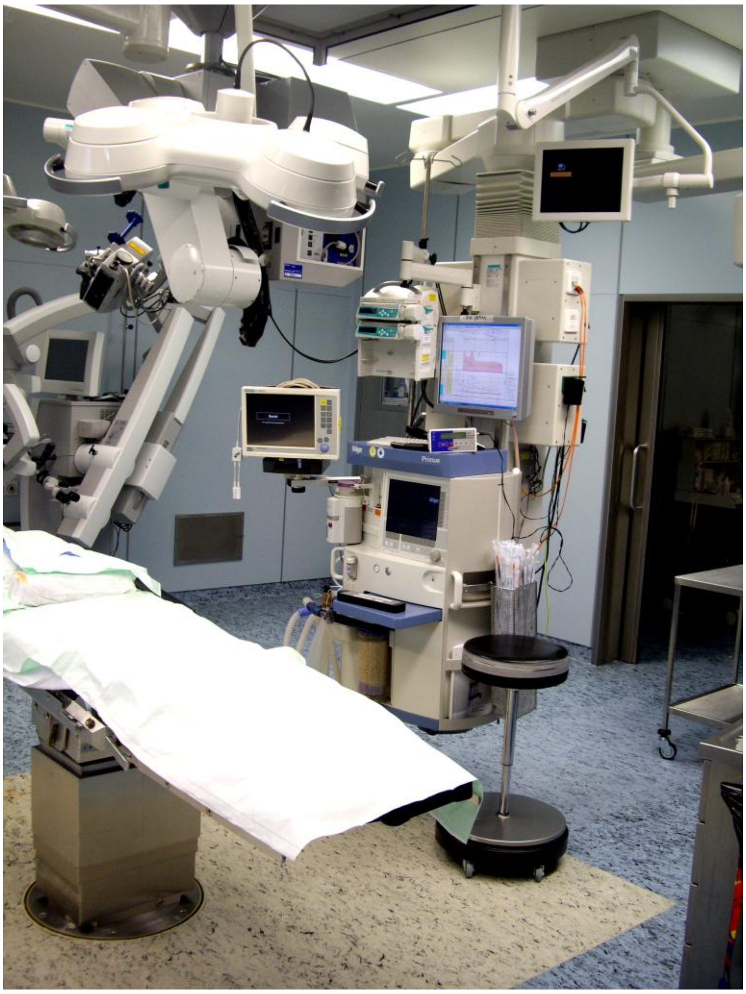
Since 2008 we have been working in close collaboration with the Innovation Center Computer Assisted Surgery (ICCAS) of Leipzig University, Germany, to create a new dynamic in this approach to the comprehension of surgical gestures. This new departure was made possible by six months spent in study in ICCAS, Leipzig, and thanks to the help of Thomas Neumuth, PhD, now scientific director of Model-Based Automation and Integration at the ICCAS. It is the Surgical Workflow Editor (SWE), a tool of his creation, which made possible the studies on which this thesis is based. The SWE is a computer program which enables the recording, live or on video, of all the gestures and actions of one or several parts of the body of one or several persons, in the form of an action-intrument-target triple. It is also the kind assistance of all the ICCAS staff and the neurosurgeons of the University Hospital of Leipzig which has made this study possible.

We chose to carry out the study in several successive steps. The validation of the SWE[44] made it possible to justify the work carried out using it, to analyse and to interpret the data recorded. In fact, the procedural strategy of the study was dependent on this validation. We chose to examine standard surgical procedures, in other words those which were frequently carried out, standardized and short in duration. We therefore made live recordings in the operating theatre of the Neurosurgery Department of the University Hospital of Leipzig. These concerned the gestures of surgeons performing spinal procedures (removal of lumbar disc herniation) and cranial procedures (removal of pituitary tumors via transsphenoidal approach). Subsequently, in the same way, similar procedures were recorded in the Neurosurgery Department of the University Hospital of Rennes.

Using the recorded data, several directions of study were possible: comparing the activity of senior and junior surgeons during similar procedures, or comparing the gestures of senior surgeons in relation to their professional experience. Another possible strategy would have been a comparison between the gestures of surgeons belonging to the two different institutions, but interpretation of the data would have been difficult.

This thesis therefore examines the three initial studies carried out on the recordings of spinal (removal of lumbar disc herniation) and cranial (removal of pituitary tumors) procedures performed in the two Neursurgery Departments of the University Hospitals of Leipzig and Rennes.

Presentation of the studies is preceded by a description of the current state of reflection and followed by a general conclusion including the future developments which can be envisaged.



Leipzig University Hospital, Neurosurgical Operative Room

Current state of reflection

During the XXth century, the age of industry made it possible to develop the tools necessary for the rise of microneurosurgery,[57] of which the most remarkable example is the use of the operating microscope.[31] Then the computer age brought in the explosion of imaging techniques and visualization systems initially for anatomical, then for functional images,[6,28,36] and subsequently their preoperative use in a multimodal environment thanks to neuronavigation systems.[5,9,24] The reason for developing increasingly high-performance preoperative visualization systems has been to assist the surgeon in defining the target point, and the functional areas to be declared no-go zones. Multimodal imaging data has also been used to develop robot systems capable of carrying out well-defined surgical procedures such as biopsies[35,36] as well as interactive virtual reality visualization systems.[29,30] Virtual reality serves a number of purposes: improving quality of accrual and reconstruction of imaging data, developing reconstruction systems for three-dimensional imaging to simulate surgical procedures and allow optimal planning of the surgical approach, and evolving training systems for specific surgical procedures.[30] However, these virtual reality systems have essentially concentrated on the most realistic rendering of tissues by three-dimensional and stereoscopic imaging, the development of tactile feedback and interactivity [30,32,49] rather than on actual understanding of the surgical procedure (who? when? what? why? how?).

As a prelude to image-based virtual planning of the surgical procedure, the surgeon must select both from his implicit knowledge (acquired through training and experience) and his explicit knowledge, in other words current medical practice concerning the case he is dealing with (evidence-based medicine) in order to answer the questions facing him: what is the best surgical strategy and how can it best be prepared?[20] A balance must be found between those two types of knowledge to ensure he has the clearest possible understanding of the procedure, and makes the right choices at the right moments, basing them on information which is both sufficient and pertinent.

Selection of information and knowledge, complete understanding of the surgical procedure and anticipation of the difficulties are the key-elements to decision-making.[26]

- Selection of anatomical, functional and physiological data and knowledge implies a high-speed interface with general information sources such as online databases or imaging networks.[32] The development of efficient easy-to-use databases, effective interfaces with medical knowledge and systems of selection thus appear as fundamental assistants to decision-making.

- Complete understanding of the surgical procedure necessarily involves a detailed description. The principal neurosurgical procedures (surgical approach, exeresis techniques…) have been described in numerous books and journals, and illustrated in a multitude of articles.[21,54] Nonetheless, no work has been done in neurosurgery on analysing instrument use: that is to say, on patterns such as the number of instruments used during an operation, their order of use, the duration of their use, their role, and their impact on the surgical process. This type of study has been carried out mainly in the context of abdominal endoscopy procedures in order to identify the effective function of instruments, so as to optimize the surgeon's movements by reducing the number of repetitive sequences (better ergonomy), to define the characteristics of a useful instrument (multifunctional) and to reduce operating time.[37] However, although the authors have succeeded in producing an objective definition of changes in instruments and gestures, they have not been able to specify all the multiple different reasons behind these changes (unexpected occurrences, individual surgeon's habitual practice…). Similarly, at a more advanced level of modeling of surgical procedure by successive stages, work has only been carried out on endoscopic abdominal surgery.[11,40] The endoscopic surgical procedure was decomposed into stages, sub-stages and successive hierarchical tasks, and a graphic model was produced.[11] This representation was suggested as a means of measuring surgical performance of experienced and novice surgeons, of assessing and comparing two different surgical techniques for the same type of operation, and of improving the performance of surgeons by training, but the study did not define these different proposals in detail. Another interesting study was carried out using the same approach of decomposition into successive stages on a cranio-facial surgical procedure.[40] The proposed model of surgical planning by the surgeon was created using a pre-defined model of standard procedure drawn from a catalogue equipped with an easily accessible database of technical information and medical knowledge. The same approach involving access to information was proposed during the procedure itself. There were several obvious goals: helping the surgeon in his preoperative planning and intra-operative decisions, and clarifying the progress of the surgical procedure.[40]

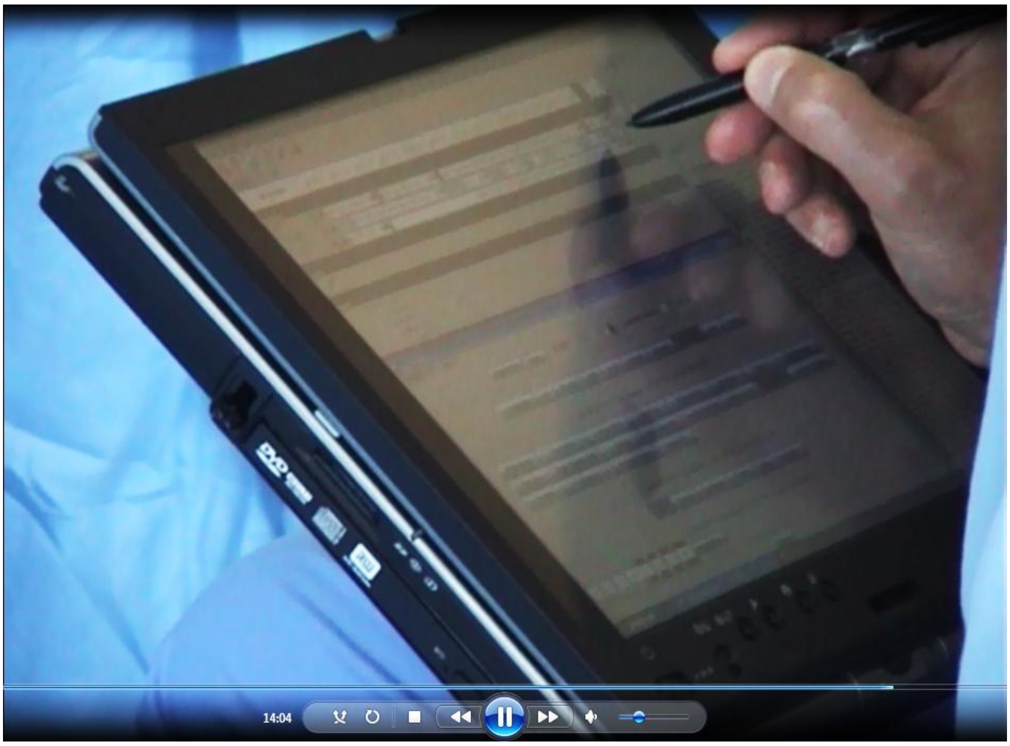
- Anticipation of the difficulties of a surgical procedure has essentially been materialized by robotized or non-robotized virtual reality systems principally designed to enable optimal understanding of three-dimensional anatomy.[13,29,30,49] The problems posed by these systems remain speed of interaction with the manipulator, spatial resolution, ergonomy and lack of information on tissue deformation. However, all the published work has underlined the useful role played by these systems in surgical training and in assisting learning processes. This form of aid in the teaching of surgical techniques and gestures has chiefly been developed in the context of mini-invasive surgery either during real endoscopic surgery[37] or on simulators.[2] The level of surgical dexterity enabling rapid performance of appropriate and effective gestures appeared to be directly related to the surgeon's level of experience and improved with training.[1,19] However, no work has so far been done on assessment and explanation of difference in gesture between an experienced surgeon and a novice during a neurosurgical procedure. Demonstrating this difference, in other words demonstrating how experience makes it possible to optimize the progress of a procedure, would be an important element in the organization of training for young surgeons. Whatever the level on which the question is examined, the final goal always seems to be the same: optimizing surgical procedures whether it be by using knowledge acquired by the surgeon through experience and training, or through information made available to him.

With the aim of better understanding and describing a neurosurgical procedure and therefore of improving its preparation and implementation, tools have had to be developed to define and store the knowledge involved. The first stage has been the emergence of tools capable of extracting information from these neurosurgical procedures before and after the operation[25,26] but also during the procedure (ICCAS Surgical Workflow Editor*).[42-46] This is a process of data accrual. The second stage would use the information stored in a database of recorded surgical procedures to assess, describe and modelize these procedures to optimize the knowledge and assistance thus provided for the surgeon.

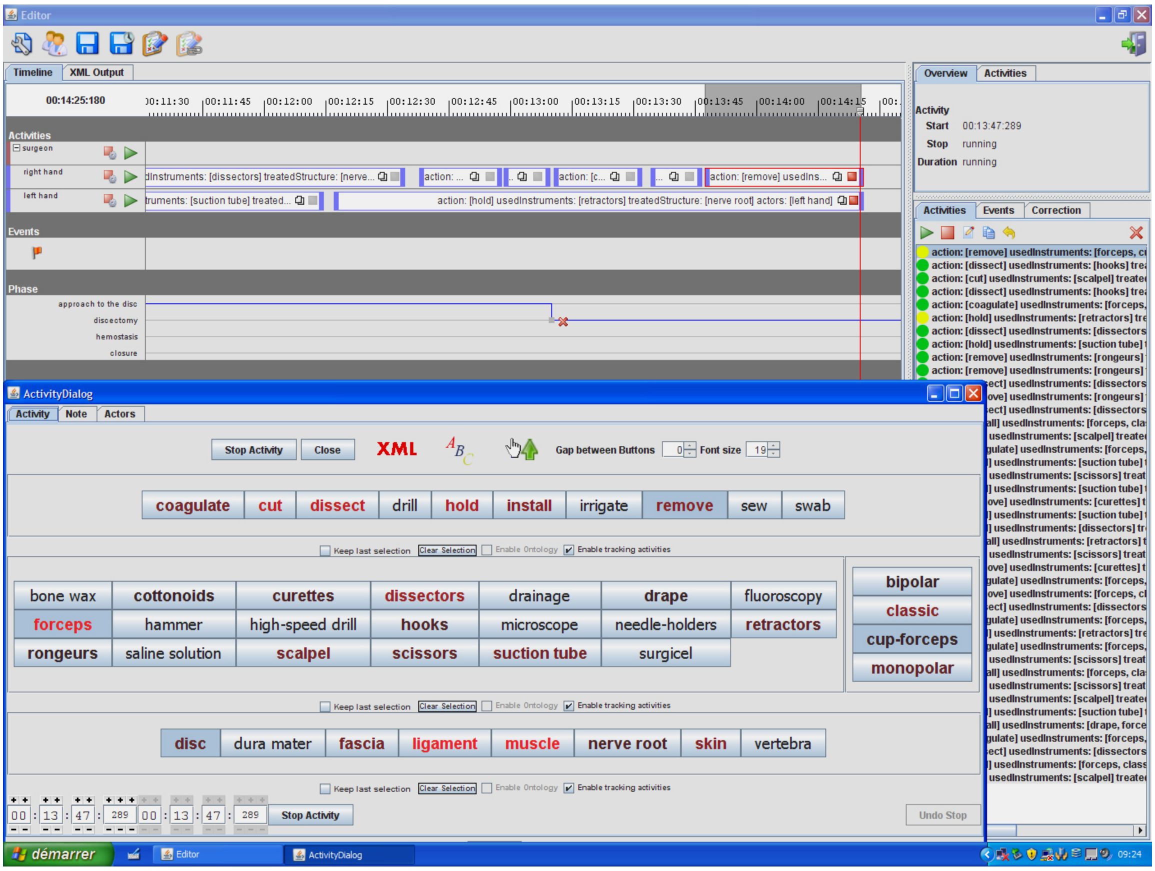
But analysis of a procedure, be it by spatial or temporal models, or description of intersurgeon comparison, requires that procedure be stereotyped or standardized by instruments, surgical approach used, or sequence of stages and involve a limited number of variables : in other words, that it be reproducible.

*The ICCAS Surgical Workflow Editor was developed in Leipzig.[42,43] This programme allows on-the-spot recording of the surgical procedure by an observer (recording of the gestures of one or more of the surgeon's limbs, however, the movements of the operating assistant or other observers may also be recorded). This software has already been used in Leipzig to record procedures in neurosurgery, heart surgery, in ear, nose and throat surgery and in ophthalmology, in the course of its validation. It allows real-time description of the surgical process: instruments used, the number of times each one is used, gestures carried out, and the number of gestures repeated, and measures the time required for each stage of the operation. The programme needs to be implemented and adapted in the context of the chosen surgical procedures so that it can deal with increased numbers of tasks and tools. (see next pages)

The observer is recording a surgical procedure under microscope with a touch-screen laptop.



Focus on the touch-screen laptop.



Screenshot of the ICCAS Surgical Workflow Editor.

The surgeon's activity performed by either the right or the left hand is recorded during this procedure of removal of lumbar disc herniation. The manual activity is characterized by an action (remove), an instrument (cup-forceps) and an anatomical structure (disc). The activities in action appear with a red square in the lines "right hand" and "left hand", or with a yellow point in the right column. The phase of discectomy is just starting after the phase of approach to the dura (red cross).

First study: lumbar disc herniation surgery

Recording of surgical processes: a study comparing senior and junior neurosurgeons during lumbar disc herniation surgery

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KEY WORDS: Discectomy, Manual activity, Skill, Surgery, Surgical practice, Surgical process, Surgical workflow

Running title: Recording of Surgical Processes

Abstract

Objective.

Evaluating surgical practice in the operating room is difficult, and its assessment is largely subjective. Recording of standardized spine surgery processes was carried out to ascertain whether any significant differences in surgical practice can be observed between senior and junior neurosurgeons.

Methods.

Twenty-four procedures of lumbar discectomies were consecutively recorded by a senior neurosurgeon. In 12 cases, surgery was entirely performed by a senior neurosurgeon with the aid of a resident, and in the 12 remaining cases, surgery was performed by a resident with the aid of a senior. The data recorded were general parameters (operating time for the whole procedure and for each step), and general and specific parameters of the surgeon's activities (number of manual gestures**,** number and duration of actions performed, of use of the instruments, of interventions on anatomical structures). The Mann-Whitney U-test was used for comparison between the 2 groups of neurosurgeons.

Results.

The operating time was statistically lower for the group of senior surgeons. The seniors statistically demonstrated greater economy in time and in gestures during the closure step, for sewing, for the use of scissors, needle-holders and forceps. The senior surgeons statistically worked for a shorter time on the skin and used fewer manual gestures on the *thoracolumbalis fascia*. The number of changes in microscope position was also statistically lower for this group.

Conclusion.

There is a relationship between surgical practice, as determined by a method of objective measurement using observation software, and surgical experience: gesture economy evolves with seniority.

Evaluating surgical practice in the operating room is difficult, and its assessment is largely subjective. Most attempts at evaluation of technical proficiency have focused on techniques that standardize the assessment process outside the operating room.[38,52] A device that can objectively and reliably quantify surgical practice could have advantages over traditional subjective evaluation, particularly as a screening tool. A system providing unbiased and objective measurement of surgical precision in the operating room, rather than just speed, could help the understanding of surgical processes and also provide a benchmark for training.[14] Decline in the standard of surgical training in Europe resulting from reduction of working hours through the European working time directive, and from financial pressures to improve productivity, have reduced opportunities to learn surgical skills in the operating theater. Therefore the use of process models involving precise descriptions of operating procedures may be an effective tool for the definition and understanding of the surgical process.[26,44]

Acquisition of surgical process models using observation software, the Surgical Workflow Editor, has been validated in a context of simulated procedures for endosopic sinus surgery.[44] Thus, recording of surgical processes with high accuracy has been established either for video, or live observations carried out by trained medical students. This report presents data recorded using this software, and analysis of removal of lumbar disc herniation in terms of surgical experience. The specific questions addressed in this study were firstly the feasibility of using the Surgical Workflow Editor in the context of live surgery, and secondly whether any significant differences in surgical practice can be observed between senior and junior neurosurgeons, in order to establish an objective series of criteria to serve as a basis both for assessment of performance and for the creation of pedagogical tools.

Materials and Methods

Twenty-four neurosurgical procedures of removal of lumbar disc herniation were consecutively recorded in the Neurosurgery Department of the Leipzig University Hospital, Germany, between June and September 2008. The patients were 10 men and 14 women with a median age of 52 years (range, 21 to 72 years).

These were exclusively patients with newly diagnosed disc herniation, no patient had undergone previous lumbar spine surgery which might be supposed to increase surgical difficulties due to fibrosis. The disc herniations were located as follows: L5S1 level: 13 cases (right/left = 8/5), L4L5 level: 8 cases (right/left = 6/2), L3L4 level: 2 cases (right/left = 1/1), L2L3 right: 1 case. In 12 cases, surgery was entirely performed by a senior neurosurgeon with the aid of a resident, and in the 12 remaining cases, surgery was performed by a junior neurosurgeon (resident) with the aid of a senior neurosurgeon. In these latter cases and when the junior surgeon experienced difficulties, the senior surgeon contributed to the surgical procedure by performing a part of the procedure.

Description of the actors

Surgery was performed by 5 different senior neurosurgeons and 5 different junior neurosurgeons. The senior neurosurgeons were considered as experts, each of them having performed more than 100 removals of lumbar disc herniation. The juniors were neurosurgical residents who had performed more than 2 years of their residency program. The two younger residents were in their third year of training and the three older residents in their seventh year. All the surgeons were right-handed.

Description of the operative procedure

The herniated disc was approached via a posterior intermyolamar route. The patient was installed in the *genu pectoral* position for this surgical procedure. Fluoroscopy was first carried out to define the precise level for the skin incision. The skin incision was made midline and the *thoracolumbalis fascia* incised on the side of the herniated disc. Muscles were then moved away from the spinous processes to allow the placing of an autostatic retractor. Another lateral x-ray image was taken before removal of the *ligamentum flavum* to confirm the level. This removal was performed under microscope (Zeiss Pentero microscope, Carl Zeiss, Germany) as was the dissection and removal of the herniated disc, and the hemostasis. Closure was achieved without a microscope by sewing first the *thoracolumbalis fascia* and then the skin.

Description of acquisition of the surgical processes

The data were acquired using a JAVA software application, the Surgical Workflow Editor.[42,43]

A screenshot of the Surgical Workflow Editor is shown in **Figure 1**.

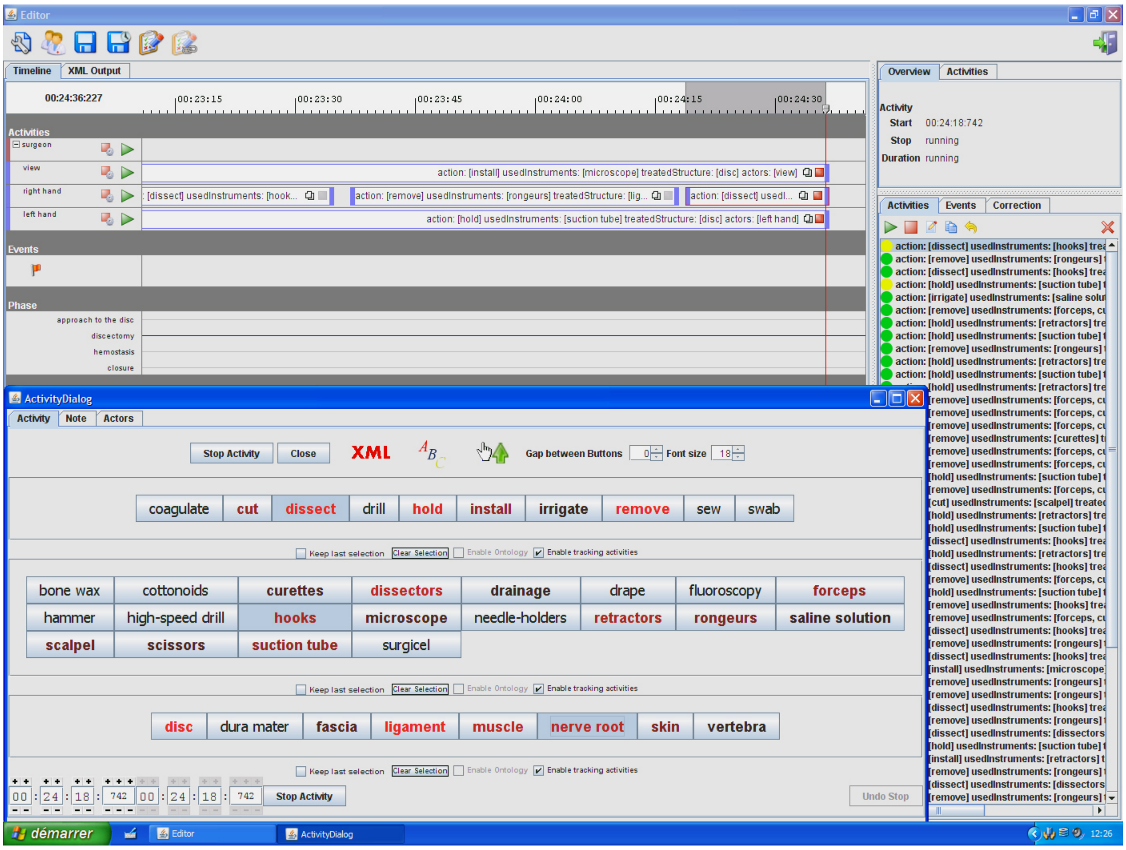

Figure 1. Screenshot of the Surgical Workflow Editor.

The mode of data acquisition was a live observation and not a video, and the observer was a senior neurosurgeon (LR). Recordings of the surgical processes for the present study started after training of the observer (LR) in the use of the Surgical Workflow Editor. This training session concerned both lumbar discectomies and other neurosurgical procedures performed in the Neurosurgery Departments of the University Hospitals of Leipzig and Rennes. The observer (LR) who recorded the surgical process was present in the operating room and performed the recordings while the surgeon was operating. A touch-screen laptop was used to facilitate the recording task.

The data structure contained a data body subdivided into tasks representing the surgical gestures. Each task had the following structure: (1) a time element containing the sub- elements: start, stop and duration, (2) an actor: the surgeon, and elements indicating the various body parts and functions used: vision, right hand, left hand, (3) the activity carried out by the surgeon, (4) the instruments used, (5) the anatomical structure treated. The activities represented the manual and visual work steps performed by the neurosurgeon during the surgical procedure. The specific content ontology of the surgical process observed (surgical actions, instruments and anatomical structures) was adapted to the procedure of lumbar disc herniation removal by the observer (LR), and rendered possible the recording of all the gestures involved in the entire process whatever the difficulties encountered by the surgeon.

Description of the recorded data

Using the Surgical Workflow Editor, we recorded general parameters of the surgical process, and general and specific parameters of the surgeon's activities. The general parameters of the surgical process were exclusively concerned with duration either of the entire process or of the different steps chosen, whereas the general and specific parameters of the surgeon's activity concerned both the cumulative duration of time and the number of activities. The recording of duration of the entire process or of the different steps therefore took into account both the time occupied by the manual activities of the surgeon, and the intervals of time between activities.

- General parameters of the procedure: the operating time was recorded from the starting time of the skin incision to the finishing time of the final skin closure. At a higher level of detail, the procedure of lumbar disc herniation removal was divided and recorded into 4 steps: (1) time of approach to the spine (from skin incision to the incision of the posterior longitudinal ligament or the removal of an excluded portion of the disc, (2) time of disc removal (from the end of the previous step to the beginning of hemostasis or closure), (3) time of hemostasis (this step may be not individualized if it was not performed), and (4) closure time (from the end of disc removal or hemostasis to the end incision closure).

- General parameters of the surgeon's activity: for the whole procedure and for each of the 4 different steps, the number of activities performed with either the right or the left hand, and the length of time each hand worked (total time of manual activities), were recorded. The operating time using the operating microscope and the number of times the surgeon changed the microscope position were recorded separately, as a visual activity, as well as the duration of fluoroscopy use after the skin incision.

- Specific parameters of the surgeon's activity: all the gestures performed by either the right or the left hand of the surgeon were recorded separately by means of a verb: coagulate, cut, dissect, drill, hold, install, irrigate, remove, sew, swab. The instruments used to perform these activities were subdivided into generic groups to avoid too much data. These instruments were: scalpels, scissors, dissectors, rongeurs (Kerrison punches), hooks, high-speed drills, suction tubes, needle-holders, saline solution, cottonoids, bone wax. Forceps were either bipolar, cup or tissue forceps. The anatomical structures treated were subdivided as follows: skin, fascia, muscle, ligament, disc, nerve root, dura mater, vertebra. No distinction was made between the different types of ligaments (the *ligamentum flavum* and the *posterior longitudinal ligament).* For the use of the operating microscope, the activity was recorded as follows: install/microscope/anatomical structure. For fluoroscopy, the activity was: install/fluoroscopy/vertebra.

Analysis of data

Results showed a nonparametric distribution. The Mann-Whitney U-test was used for comparison between the groups of senior and junior neurosurgeons. A P value of less than 0.05 was deemed significant.

Results

Duration and number of gestures

The time taken and the number of hand movements required to perform the lumbar discectomies are respectively shown in **Tables 1 and 2**.

For the whole procedure and for each step, the number of activities performed either with the right or the left hand and the length of time each hand was active are also presented.

TABLE 1. Mean time taken to perform the whole surgical procedure and each step according to surgical experience

	Time (seconds)			*P* value
	Senior & Junior (n = 24)	Senior (n = 12)	Junior (n = 12)	
Operating time	4855 (1448)	4228 (1079)	5483 (1537)	**0.039**[a]
Right hand	3554 (1157)	3228 (883)	3880 (1337)	0.347
Left hand	3635 (1430)	3386 (1182)	3884 (1657)	0.551
Approach to the disc	2377 (977)	2057 (757)	2697 (1095)	0.104
Right hand	1609 (713)	1500 (607)	1719 (817)	0.410
Left hand	2085 (931)	1920 (679)	2251 (1136)	0.478
Discectomy	1441 (692)	1350 (751)	1533 (647)	0.319
Right hand	1196 (578)	1127 (625)	1266 (545)	0.378
Left hand	987 (720)	1107 (809)	867 (638)	0.315
Hemostasis	416 (462)	344 (331)	476 (556)	0.656
Right hand	266 (314)	211 (226)	377 (310)	0.603
Left hand	301 (473)	153 (203)	609 (430)	0.463
Closure	536 (221)	409 (169)	664 (196)	**0.006**[a]
Right hand	526 (215)	443 (170)	611 (230)	**0.039**[a]
Left hand	539 (219)	455 (192)	624 (219)	0.078

[a] Statistically significant
Results are the mean, with the standard deviations in parentheses for Table 1 to 6.

TABLE 2. Mean number of manual gestures in the whole surgical procedure and in each step according to surgical experience

	Number of activities performed			*P* value
	Senior & Junior (n = 24)	Senior (n = 12)	Junior (n = 12)	
Operating time	138.8 (40.2)	139.8 (40.1)	137.8 (41.9)	0.921
Right hand	112.9 (34.9)	113.2 (36.0)	112.5 (35.3)	0.944
Left hand	26.0 (9.7)	26.6 (9.4)	25.3 (10.3)	0.660
Approach to the disc	70.1 (28.1)	71.3 (22.1)	68.9 (34.1)	0.486
Right hand	53.6 (22.3)	54.2 (18.0)	53.1 (26.8)	0.600
Left hand	16.5 (8.8)	17.1 (8.8)	15.8 (9.1)	0.831
Discectomy	45.8 (22.8)	47.7 (27.0)	44.0 (18.7)	0.854
Right hand	41.3 (18.5)	42.1 (21.9)	40.7 (15.2)	0.876
Left hand	4.5 (5.5)	5.6 (6.4)	3.3 (4.4)	0.308
Hemostasis	10.5 (9.9)	12.4 (9.8)	9.0 (10.2)	0.419
Right hand	9.4 (9.3)	11.1 (9.1)	8.0 (9.6)	0.379
Left hand	1.1 (1.0)	1.3 (1.2)	0.9 (0.8)	0.483
Closure	14.1 (5.5)	11.5 (4.4)	16.7 (5.4)	**0.031**[a]
Right hand	10.0 (3.8)	8.7 (3.8)	11.3 (3.4)	0.161
Left hand	4.1 (2.6)	2.8 (1.3)	5.3 (2.9)	**0.016**[a]

[a] Statistically significant

The results demonstrated that the operating time was statistically lower for the group of senior surgeons ($p < 0.039$). The difference between the 2 groups of surgeons was statistically significant both in the time taken ($p < 0.006$) and in the number of activities performed ($p < 0.031$) to achieve the closure step, with the senior surgeons demonstrating greater economy in time and in gestures during this step. Furthermore, the right hand worked a shorter time ($p < 0.039$) and the left hand carried out fewer activities ($p < 0.016$) in the group of senior surgeons.

Actions

The time taken and the number of actions (recorded by using a verb) performed either with one or the other hand during the whole procedure are presented in **Table 3**.

TABLE 3. Mean number and duration of actions performed either with one or the other hand during the whole procedure[a]

Action	Senior & Junior (n = 24)	Senior (n = 12)	Junior (n = 12)	*P* value
Cut				
N	10.6 (4.6)	9.9 (3.9)	11.2 (5.2)	0.636
Time	166 (82)	151 (81)	180 (83)	0.291
Coagulate				
N	12.5 (5.7)	11.4 (4.5)	13.6 (6.7)	0.520
Time	322 (258)	231 (96)	414 (335)	0.089
Dissect				
N	26.3 (9.7)	25.3 (7.7)	27.3 (11.6)	0.899
Time	751 (339)	730 (368)	771 (324)	0.843
Drill				
N	3.9 (1.9)	3.7 (2.5)	4.0 (1.7)	0.858
Time	236 (99)	186 (65)	258 (108)	0.383
Hold				
N	24.7 (14.0)	27.5 (17.6)	21.8 (9.1)	0.561
Time	3504 (1519)	3374 (724)	3633 (1757)	1.000
Install				
N	24.8 (9.6)	20.8 (4.5)	28.7 (11.7)	0.123
Time	3809 (1287)	3261 (724)	4357 (1511)	0.060
Irrigate				
N	5.4 (3.8)	6.4 (4.1)	4.6 (3.5)	0.284
Time	97 (71)	89 (59)	103 (81)	0.759
Remove				
N	37.4 (11.5)	39.7 (12.4)	35.0 (10.6)	0.086
Time	1505 (621)	1421 (519)	1589 (722)	0.977
Sew				
N	6.7 (2.7)	5.5 (2.2)	8.0 (2.5)	**0.014[b]**
Time	453 (212)	364 (152)	542 (231)	**0.024[b]**
Swab				
N	2.0 (1.5)	2.4 (1.8)	1.5 (0.5)	0.545
Time	29 (36)	37 (44)	15 (5)	0.615

[a] N, mean number of actions during the whole surgical procedure; Time, mean duration of the action performed (seconds).
[b] Statistically significant

The results showed statistically significant differences for sewing, with the senior surgeons demonstrating greater economy in time ($p < 0.024$) and in number of gestures ($p < 0.014$) to complete this action.

Instruments

The time taken and the number of times the instruments were used during the entire procedure are presented in **Table 4**.

TABLE 4. Mean number and duration of use of the instruments with one or the other hand during the whole procedure[a]

Instrument	Senior & Junior (n = 24)	Senior (n = 12)	Junior (n = 12)	*P* value
Forceps				
N	37.5 (12.6)	34.8 (10.5)	40.0 (14.4)	0.580
Time	1609(618)	1289 (262)	1930 (712)	**0.005[b]**
Tissue forceps				
N	9.7 (5.4)	8.1 (3.7)	11.4 (6.4)	0.158
Time	777 (373)	615 (199)	940 (439)	0.078
Bipolar forceps				
N	12.8 (6.2)	11.6 (4.6)	14.1 (7.5)	0.558
Time	334 (274)	237 (100)	432 (356)	0.114
Cup forceps				
N	14.8 (6.2)	15.1 (8.0)	14.6 (3.9)	0.944
Time	495 (266)	433 (181)	558 (326)	0.378
Scalpels				
N	5.7 (2.9)	5.7 (3.1)	5.7 (2.9)	0.875
Time	102 (64)	109 (76)	95 (51)	1.000
Scissors				
N	6.0 (3.0)	4.7 (1.8)	7.2 (3.5)	**0.050[b]**
Time	89 (61)	54 (26)	124 (66)	**0.001[b]**
Hooks				
N	12.0 (9.5)	11.7 (9.5)	12.4 (10.0)	0.745
Time	360 (285)	345 (270)	374 (310)	0.977
Retractors				
N	11.8 (5.0)	11.8 (4.4)	11.7 (5.6)	0.808
Time	249 (139)	244 (145)	254 (139)	0.641
Dissectors				
N	15.1 (6.4)	16.3 (8.0)	14.0 (4.1)	0.324
Time	444 (284)	501 (379)	387 (135)	0.921
Rongeurs				
N	19.9 (8.0)	21.1 (8.1)	18.7 (8.0)	0.401
Time	996 (519)	942 (498)	1050 (555)	0.755
High-speed drill				
N	3.9 (1.9)	3.7 (2.5)	4.0 (1.7)	0.858
Time	236 (99)	185 (65)	258 (108)	0.383
Needle-holders				
N	6.8 (2.6)	5.6 (2.0)	8.0 (2.5)	**0.014[b]**
Time	459 (203)	376 (134)	542 (231)	**0.033[b]**
Suction tube				
N	15.9 (12.2)	20.0 (15.5)	11.8 (6.1)	0.172
Time	2569 (1298)	2449 (772)	2689 (1701)	1.000
Cottonoids				
N	4.2 (3.8)	4.5 (3.2)	4.0 (4.4)	0.475
Time	85 (93)	76 (75)	94 (112)	0.887

Drainage				
N	2.2 (0.5)	86.6 (59.2)	2.2 (0.6)	0.846
Time	28 (12)	87 (59)	90 (33)	0.270
Bone wax				
N	1.2 (0.7)	41.4 (29.2)	1.0 (0.0)	1.000
Time	38 (24)	41 (29)	31 (14)	0.857
Saline solution				
N	5.3 (3.8)	6.2 (4.0)	4.6 (3.5)	0.400
Time	96 (70)	87 (58)	103 (81)	0.759
Drape				
N	1.4 (0.7)	1.0 (0.0)	1.6 (0.8)	0.500
Time	28 (12)	22 (16)	30 (11)	0.667
Fluoroscopy				
Time	221.0 (110.0)	201.0 (85.4)	243.0 (135.0)	0385

[a] N, mean number of uses of the instrument during the whole surgical procedure; Time, mean duration of use of the instrument (seconds).
[b] Statistically significant

The results showed statistically significant differences for the use of scissors and needle-holders, with the senior surgeons demonstrating greater economy both in time and in number of gestures. The time of use for forceps (all types of forceps considered) was statistically shorter in the group of senior surgeons ($p < 0.005$), with a shorter time of use for tissue forceps, although non significant ($p = 0.078$).

Results for microscope use are summarized in **Table 5**.

TABLE 5. Mean number and duration of uses of the microscope during the whole procedure[a]

	Senior & Junior (n = 24)	Senior (n = 12)	Junior (n = 12)	*P* value
Microscope				
N	10.1 (6.1)	7.0 (3.4)	13.2 (6.7)	**0.019**[b]
Time	3337 (1259)	3077 (996)	3596 (1475)	0.514

[a] N, mean number of changes of microscope position during the whole surgical procedure; Time, mean time of use of microscope (seconds).
[b] Statistically significant

The results showed that the number of changes in microscope position was statistically lower for the group of the senior surgeons ($p < 0.019$), although the time of its use was not statistically different between the 2 groups.

Anatomical structures

The times and number of gestures concerning intervention on the anatomical structures during the whole procedure are presented in **Table 6**. The results showed that the senior surgeons statistically worked a shorter time on the skin ($p < 0.001$) and used fewer manual gestures on the *thoracolumbalis fascia* ($p < 0.006$).

TABLE 6. Mean number and duration of interventions on the anatomical structures during the whole procedure[a]

Anatomical structure	Senior & Junior (n = 24)	Senior (n = 12)	Junior (n = 12)	*P* value
Skin				
N	15.6 (5.0)	13.8 (2.9)	17.3 (6.1)	0.181
Time	804 (394)	561 (184)	1048 (401)	**0.001[b]**
Lumbosacral fascia				
N	7.7 (3.4)	5.9 (2.5)	9.6 (3.1)	**0.006[b]**
Time	440 (263)	444 (279)	435 (260)	0.977
Muscles				
N	20.1 (9.0)	19.9 (8.5)	20.4 (9.9)	0.988
Time	759 (732)	788 (896)	731 (561)	0.713
Ligaments				
N	50.9 (19.7)	51.8 (17.8)	49.9 (22.2)	0.745
Time	5366 (2142)	5092 (1728)	5640 (2539)	0.932
Disc				
N	24.7 (11.5)	25.4 (15.3)	23.9 (6.2)	0.831
Time	1534 (1451)	1383 (1284)	1684 (1645)	0.514
Nerve root				
N	17.7 (12.0)	17.7 (13.0)	17.7 (11.5)	0.989
Time	562 (488)	498 (487)	626 (501)	0.386
Dura mater				
N	5.3 (4.0)	6.1 (4.9)	4.6 (3.2)	0.524
Time	562 (668)	454 (556)	648 (765)	0.762
Vertebra				
N	11.0 (7.2)	10.3 (5.2)	11.6 (9.0)	0.853
Time	868 (1014)	648 (440)	1089 (1360)	0.434

[a] N, mean number of interventions on the anatomical structure during the whole surgical procedure; Time, mean duration (seconds).
[b] Statistically significant

Discussion

This study aimed first at evaluating the feasibility of using Surgical Workflow Editor to produce an accurate recording of the manual gestures of neurosurgeons during a standardized surgical procedure, and secondly at a specific analysis of this recording according to surgical experience.

Results of analysis

Results showed that the mean time necessary for the entire surgical procedure was statistically shorter for the senior surgeon group. The detailed analysis demonstrated that duration of the first three steps in the procedure (approach, discectomy, hemostasis) was shorter for the senior surgeon group without being statistically significant. Only the final closure step was significantly shorter in this group. These results may be explained by the assistance given by the senior surgeon in the surgical procedures carried out by the junior. This probably reduced the duration of the three steps (approach, discectomy, hemostasis). The closure step was the most representative of the surgeon's gestures, since it was entirely performed by the senior surgeon in the senior group and by the junior in the junior group. During this step it was therefore possible to record the manual activity of the surgeons in identical conditions, measure it and compare it in the context of an identical surgical gesture.

Differences observed

The differences observed between senior and junior surgeons concerned both the duration of the step and the number of gestures performed. The closure step was observed to be significantly shorter in the senior surgeon group, particularly for those activities performed by the right hand, and the total number of gestures was significantly lower for the senior group. It was also possible to establish in detail that the saving in time and in number of gestures observed among the senior group specifically concerned: sewing, the use of scissors, needle-holders and forceps, and the skin and *lumbosacral fascia*.

These results seem coherent, since the differences concerned not only the principal activity carried out during the closure step, but also the instruments and anatomical structures involved in this step.

A clear tendency was observed among the senior surgeons to use fewer gestures than the juniors to carry out the same task, as is shown by the use of the microscope: the number of position changes being twice as great in the junior group, although the overall time of use did not vary significantly from one group to the other. These results are a good illustration of the economy of gestures observed among senior surgeons, and of the less well-developed technique of juniors, whose over-frequent adjustments of microscope position have a negative effect, interrupting the surgeon's concentration and the fluidity of the gesture.

The question remains whether the results observed really reflect a difference in manual dexterity between the two groups of surgeons with different levels of experience. Manual dexterity of surgeons has mostly been analysed outside the operating theater using laboratory simulation in both open and laparoscopic models as well as in virtual reality.[38,52,41]

Several reasons led to the use of simulations rather than evaluations within the operating theater to assess skill.[16] For example, inanimate simulation with synthetic models allowed exact duplication of conditions for participants and therefore more valid comparison of performance between individuals. Methods of assessing operative skill of surgeons and their trainees were both qualitative (direct observation of the task followed by scoring)[51,55] and quantitative. Quantitative measurement of manual dexterity by motion analysis (time taken and number of movements) has been studied using bench test models of surgery like suturing and knot-tying tasks.[3,7,15] These experiments showed that more experienced surgeons performed these tasks in a shorter time than junior trainees.

This has raised the question why experienced surgeons were taking less time to achieve the task. Were their movements more rapid, or were they making fewer gestures, thus achieving a faster time? This question emphasized the necessity of measuring both the number of movements and the time to give a true reflection of dexterity. The experiments using simple bench tasks confirmed that experienced surgeons were more economical with their movements, performing the exercises with fewer movements rather than with higher speed.[7] But performance within the operating theatre does not depend only on technical skill. The operating room can be a threatening and stressful environment: surgeons may behave differently, and the question of transferring observation of technical skills from laboratory to live surgery remains unanswered.[3]

The results from this initial study are promising and may give the beginning of a response: analysis of the manual activities of the surgeon in real surgical practice showed similar results to analysis of surgical skill in synthetic models. The experienced surgeons (senior) were more economical with their movements than the inexperienced ones (junior) during a mechanical step (closure). This observation was not so clear for activities performed during non-mechanical steps like the approach and the discectomy, where the manual gestures were not different from one group to the other.

Although the operating room should be the ideal location for the assessment of surgical practice and the acquisition of primary technical skills, several reasons are currently making it difficult in our teaching institutions[4]: the financial pressure that forces surgeons to be more and more efficient in the operating room, the increasing number of patients with complex surgical problems that demand the skill of expert surgeons working at maximum efficiency, and finally ethical concerns about teaching basic skills using a patient.

Scope of the study

The use of Surgical Workflow Editor for recording surgical processes in the operating room has some limitations. Firstly, the need to record standardized operations for a valid comparison may involve some difficulties, as all patients are different. In this study, we recorded a frequent and reproducible surgical process. We chose to avoid recording more complicated surgical processes, such as patients with previous lumbar spine surgery for whom the procedure would be longer due to the dissection of fibrosis. Secondly, recording surgical processes may be time-consuming in the long term. In a previous work, Neumuth et al.[44] demonstrated that trained medical students can be highly accurate observers, which may make it possible to increase the number of routine observers for recording.

Nevertheless, the Surgical Workflow Editor appeared to be a method of assessment of surgical practice appropriate for use in the context of live surgery. According to Moorthy et al.,[38] a method that makes the assessment process objective should also be valid and reliable. Indeed, the assessment of technical skills by direct observation, as currently occurs in the operating room, is influenced by subjectivity: the assessment is global and not based on specific criteria.

Furthermore, morbidity and mortality data, often used as surrogate markers of operative performance, are influenced by patient characteristics and thus do not truly reflect surgical performance.[10] The existence of several criteria that can be recorded using the Surgical Workflow Editor and the possibility of adapting them to each surgical process confirms our method of assessing surgical skills as an objective one, and completes the arsenal of methods for the measurement of surgical practice and dexterity.

Conclusion

This study has served to illustrate the relationship between surgical practice, as determined by a method of objective measurement using observation software, and surgical experience in a context of live surgery. It has allowed us to establish that gesture economy evolves with seniority.

This result is encouraging and will hopefully spur further investigations into other surgical procedures, or fields of medicine that require proficiency in manual dexterity.

The use of objective measurement may make it possible to define a standard of performance for a given procedure carried out in similar circumstances. This standard could potentially be of use both in the evaluation of surgical skills and in the training of junior surgeons.

Second study: pituitary tumor surgery

Pituitary tumor surgery via transsphenoidal approach.

Part I: A study comparing otorhinolaryngologists and neurosurgeons operating by transnasal route, using recording of surgical processes

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KEY WORDS: Manual activity, Pituitary tumor, Surgical workflow, Surgical process, Transnasal route, Transsphenoidal approach

Running head: Comparison between ORL and neurosurgeons during transnasal route

Abstract

Object.

Recording of transnasal transsphenoidal approach for pituitary tumors was carried out to ascertain whether it was possible to observe any significant differences in surgical practice between senior otorhinolaryngologists and neurosurgeons.

Methods.

Twenty-seven surgical procedures involving transsphenoidal approach of pituitary tumors were consecutively recorded by a senior neurosurgeon. Transnasal transsphenoidal approach was carried out by 3 different senior ORL (9 cases), by a neurosurgeon with experience of 200 procedures (8 cases) and by a neurosurgeon who had performed more than 1000 (10 cases). Data recorded were: firstly general parameters (overall operating time and time taken for each step: preparation of the nose and approach to the dura mater); and secondly general and specific aspects of the surgeon's activities (number of manual gestures, number and duration of actions performed, use of the instruments, and interventions on anatomical structures). The Kruskal-Wallis test was used for comparison between the 3 groups of surgeons.

Results.

The operating time for approach to the dura mater was statistically shorter for the most experienced neurosurgeon. He also used statistically fewer gestures to perform both this step and the preparation of the nose. During approach to the dura mater, he also took a shorter time and used fewer gestures for coagulating, holding and installing instruments (scissors, retractors, rongeurs, suction tube and bipolar forceps), and removing tissue. The number of changes in microscope positioning and the duration of its use were also statistically lower.

Conclusions.

Surgical expertise founded on experience is synonymous with shorter procedures and greater efficiency in manual gesture during the most mechanical phases, more particularly with the dominant hand.

Surgical Workflow Editor is an observation software which allows high-accuracy recording of surgical processes.[44-46] This software was used in a previous study concerning standardized spinal surgery: removal of a lumbar disc herniation.[53] The study demonstrated that it was possible to make a detailed real-time recording of a surgeon's manual activity, and to use the recordings to analyze the procedure both for purposes of comprehension and education, and for comparison of the manual gestures of 2 groups of neurosurgeons with differing levels of experience.

The transsphenoidal approach to the sella turcica has evolved since its revival in the late 1960s with the addition first of intraoperative fluoroscopy, operative microscope and more recently endoscope, neuronavigation and real-time intra-operative magnetic resonance imaging (MRI).[22,27,33,34] Transnasal transsphenoidal approach is as of now the preferred approach for lesions confined to the sella turcica and although there exist some variations, this procedure is a standard surgical process like lumbar disc herniation removal. It therefore constitutes an excellent model for recording and comparison of manual gestures between different groups of surgeons. Moreover, the transnasal transsphenoidal approach can be performed either by otorhinolaryngologists (ORL) or by neurosurgeons according to the practice of the institution concerned, as can the translabyrinthine approach for schwanommas of the acoustic nerve. It therefore seemed particularly interesting and innovative to compare surgeons with different specialties in order to analyze their habits and the differences in manual activities during similar procedures. We also wished to analyze the gestures of senior surgeons with differing experience and compare the results with those previously obtained concerning groups of junior and senior neurosurgeons.

Materials and Methods

Twenty-seven surgical procedures involving transsphenoidal approach of pituitary tumors were recorded consecutively. Seventeen were recorded in the Neurosurgery Department of Leipzig University Hospital, Germany, between May and October 2008, and ten in the Neurosurgery Department of Rennes University Hospital, France, between November 2008 and January 2009. The patients were 11 men and 16 women with a median age of 49 years (range, 16 to 80 years). These patients all had newly diagnosed tumors, none had undergone previous surgery which might be supposed to increase surgical difficulties as a result of fibrosis.

The tumors were non-functioning pituitary adenomas in 17 cases, prolactinomas in 6 cases, GH-secreting adenomas in 3 cases, ACTH-secreting tumor with Cushing's disease in one case.

Description of the participants

Transnasal transsphenoidal approach was performed in 9 cases by 3 different senior ORL from the ORL Department of Leipzig University Hospital, Germany. In the remaining 18 cases, surgery was carried out by 2 senior neurosurgeons: CT in 8 cases in Leipzig and GB in 10 cases in Rennes. The 3 ORL were all familiar with the transsphenoidal route, and the senior neurosurgeons were considered as experts on pituitary surgery via the transsphenoidal approach in their respective institutions. CT had performed about 200 pituitary surgeries and GB more than 1000.

All the surgeons were right-handed.

Description of the operating procedure

A transnasal route was used in all cases. Positioning of the patient was different in the 2 institutions. In Leipzig, the patient was placed in the *decubitus dorsal* position, the surgeon at the head of the table, operating from above (**Figure 1**). In Rennes, the neurosurgeon (GB) preferred to install the patient in a lawn-chair position to reduce venous pressure and bleeding. In that position, the patient’s head was oriented toward the surgeon to facilitate gestures and lateral fluoroscopy (**Figure 2**). Intraoperative lateral fluoroscopy was used in the 2 institutions.

A L-shaped vertical incision of the nasal mucosa was first performed to detach the homolateral layer of the mucosa from the septum. The septum was then incised to detach the second layer of the mucosa and was removed to allow access to the vomer. A transsphenoidal speculum was put in place, its position and trajectory confirmed by fluoroscopy. The sphenoid sinus was opened under microscope (Zeiss Pentero microscope, Carl Zeiss, Germany) by removal of the rostrum of the sphenoid. The sphenoid sinus mucous membrane was then entirely excised. The sellar floor was taken off to expose the dura mater of the pituitary fossa as well as the anterior limit of the left and right cavernous sinus.

Figure 1: *Decubitus dorsal* position with the surgeon at the head of the table

Figure 2: Lawn-chair position

Description of acquisition of the surgical processes

The data were acquired using a JAVA software application, the Surgical Workflow Editor.[42-43]

A screenshot of the Surgical Workflow Editor is shown in **Figure 3**.

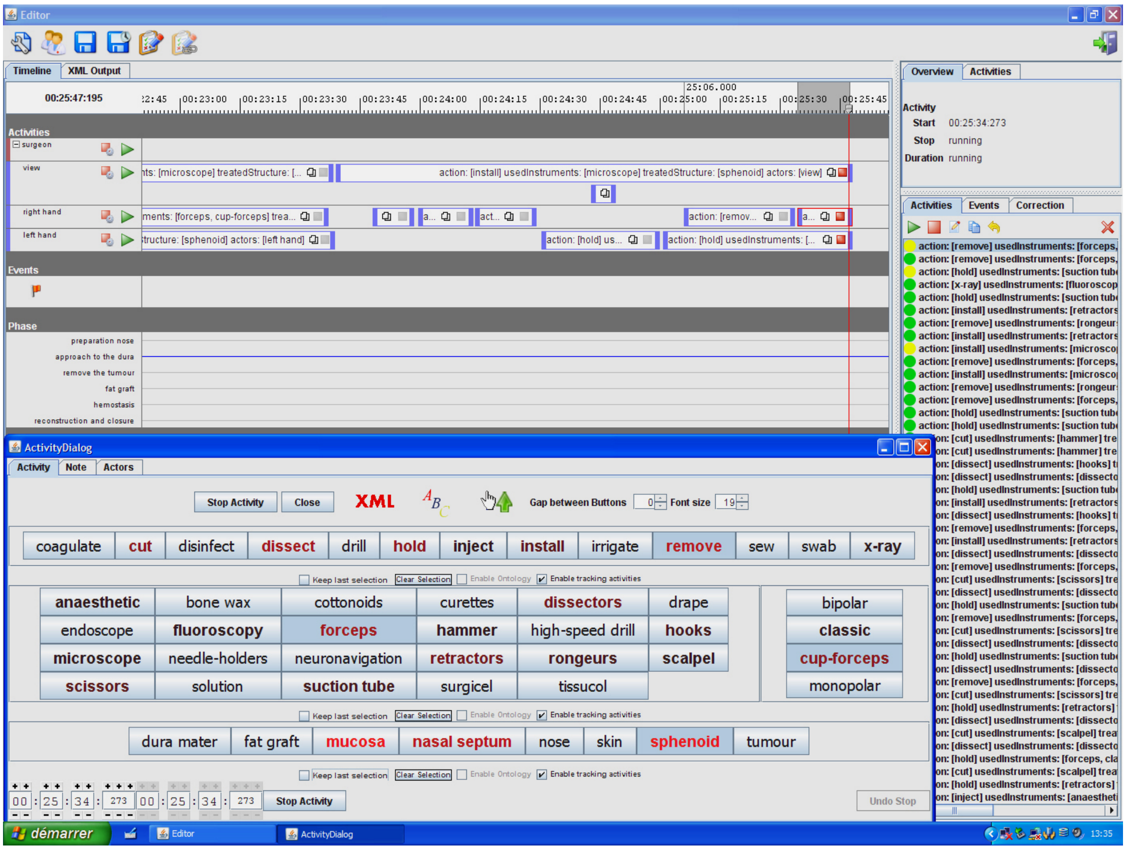

Figure 3. Screenshot of the Surgical Workflow Editor during the procedure of transnasal route to pituitary tumor

The mode of data acquisition was live observation, and the observer was a senior neurosurgeon (LR). Recordings of the surgical processes for the present study started after training of the observer in the use of the Surgical Workflow Editor. This training session concerned neurosurgical procedures performed in the Neurosurgery Departments of the University Hospitals of Leipzig and Rennes. The observer who recorded the surgical process was present in the operating room and performed the recordings while the surgeon was operating. A touch-screen laptop was used to facilitate the recording task.

The data structure contained a data body subdivided into tasks representing the surgical gestures. Each task had the following structure: (1) a time element containing the sub-elements: start, stop and duration, (2) an actor: the surgeon, and elements indicating the various body parts and functions used: vision, right hand, left hand, (3) the activity carried out by the surgeon, (4) the instruments used, (5) the anatomical structure treated. The activities represented the manual and visual work steps performed by the neurosurgeon during the surgical procedure. The specific content ontology of the surgical process observed (surgical actions, instruments and anatomical structures) was adapted to the procedure of transsphenoidal approach of pituitary tumors by the observer (LR), and rendered possible the recording of all the gestures involved in the process.

Description of the recorded data

Using the Surgical Workflow Editor, we recorded general parameters of the surgical process, and general and specific parameters of the surgeon's activities. The general parameters of the surgical process exclusively concerned duration of the 2 different steps chosen, whereas the general and specific parameters of the surgeon's activity concerned both the cumulative duration of time and the number of activities. The recording of duration of the different steps therefore took into account both the time occupied by the manual activities of the surgeon, and the intervals of time between activities.

- General parameters of the procedure: The operating time was recorded from the start of the anesthetic infiltration of the nasal mucosa to the finish of the removal of the sellar floor. The procedure of transsphenoidal approach was divided into 2 steps: (1) time to taken to infiltrate the nasal mucosa with anesthetic and (2) time taken to approach and remove the sellar floor.

- General parameters of the surgeon's activity: for each of the 2 steps, the number of activities performed with either the right or the left hand, and the length of time each hand worked (total time of manual activities), were recorded. Time spent using the operating microscope and the number of times the surgeon changed the microscope position were recorded separately, as a visual activity, as was the duration of fluoroscopy use after the mucosa incision.

- Specific parameters of the surgeon's activity: all the gestures performed by either the right or the left hand of the surgeon were recorded separately by means of a verb: coagulate, cut, dissect, drill, hold, inject, install, irrigate, remove, sew, swab, X-ray. The instruments used to perform these activities were subdivided into generic groups to avoid too much data. These instruments were: anesthetic, bone wax, cottonoids, dissectors, hammer, high-speed drill, hooks, retractors, rongeurs (Kerrison punches), saline solution, scalpel, scissors, suction tubes. Forceps were either bipolar, cup or tissue forceps. The anatomical structures treated were subdivided as follows: nose, mucosa, nasal septum, sphenoid, dura mater.

For the use of the operating microscope, the activity was recorded as follows: install/microscope/anatomical structure. For fluoroscopy, the activity was: x-ray/fluoroscopy/sphenoid.

Analysis of data

The Kruskal-Wallis test was used for comparison between the 3 groups of surgeons. A p value of less than 0.05 was deemed significant.

Results

Duration and number of gestures

The time taken and the number of hand movements required to perform the preparation of the nose and the approach to the dura mater are shown respectively in **Tables 1 and 2**.

For each step, the number of activities performed with the right or the left hand and the length of time each hand was active are also presented.

TABLE 1: Mean time taken to perform each step according to the 3 groups of surgeons, and mean time each hand had worked

	Mean Time in Seconds			
	Leipzig ORL (n = 9)	Leipzig Neurosurgeons (n = 8)	Rennes Neurosurgeon (n = 10)	p Value
Preparation nose	193 (192)	200 (68)	156 (40)	0.252
Right hand	47 (24)	81 (25)	154 (38)	**0.000**[a]
Left hand	193 (192)	197 (68)	155 (38)	0.295
Approach to the dura	2947 (809)	3260 (1571)	1988 (875)	**0.010**
Right hand	1768 (596)	1593 (851)	920 (509)	**0.004**
Left hand	2140 (882)	2622 (1549)	1598 (737)	0.202

TABLE 2: Mean number of manual gestures in each step according to the 3 groups of surgeons

	Mean Number of Activities Performed			p Value
	Leipzig ORL	Leipzig Neurosurgeons	Rennes Neurosurgeon	
Preparation nose	3.3 (1.8)	3.7 (1.9)	1.9 (0.3)	**0.010**
Right hand	2.3 (1.6)	2.6 (1.9)	1.0 (0.0)	**0.004**[a]
Left hand	1.0 (0.0)	1.1 (0.4)	0.9 (0.3)	0.689
Approach to the dura	83.8 (27.0)	76.0 (23.0)	58.7 (26.0)	**0.036**
Right hand	74.2 (24.6)	66.1 (20.1)	48.2 (19.5)	**0.027**
Left hand	9.6 (4.0)	9.9 (4.4)	10.5 (7.0)	0.965

Standard deviations are in parentheses for Table 1 to 6. [a] statistically significant

The results demonstrate that the operating time of approach to the dura mater was statistically shorter for the most experienced neurosurgeon from Rennes ($p < 0.010$). The differences between the 3 groups of surgeons were statistically significant both in time taken and in number of activities performed, with the Rennes neurosurgeon demonstrating greater economy in time ($p < 0.004$) and in gestures ($p < 0.027$) with his right hand during the approach to the dura mater. He also used statistically fewer gestures to perform these 2 steps.

Actions

The time taken and the number of actions (recorded by using a verb) performed either with one or the other hand during each step are presented in **Table 3**.

TABLE 3: Mean number and duration of actions performed either with one or the other hand in each step[a]

Action	Leipzig ORL	Leipzig Neurosurgeons	Rennes Neurosurgeon	p Value
Preparation nose				
Hold				
N	1.2 (0.8)	1.8 (1.0)	1.0 (0.0)	**0.050[b]**
Time	174 (194)	197 (68)	155 (38)	0.238
Inject				
N	1.7 (1.1)	2.5 (2.4)	1.0 (0.0)	**0.032**
Time	38 (23)	85 (40)	154 (38)	**0.000**
Approach to the dura				
Coagulate				
N	10.2 (5.3)	18.0 (7.3)	2.2 (3.9)	**0.000**
Time	309 (157)	405 (186)	55 (114)	**0.000**
Cut				
N	2.1 (2.7)	1.3 (0.5)	4.1 (1.2)	**0.000**
Time	48 (74)	14 (7.6)	65 (31)	**0.000**
Dissect				
N	15.4 (11.0)	12.5 (5.9)	7.4 (3.9)	0.057
Time	198 (113)	229 (140)	135 (86)	0.143
Drill				
N	0.0 (0.0)	0.4 (0.7)	1.8 (3.1)	0.203
Time	0.0 (0.0)	14 (30)	107 (196)	0.203
Hold				
N	27.4 (14.7)	15.3 (4.2)	17.0 (7.7)	**0.020**
Time	2398 (876)	2783 (1532)	1615 (733)	**0.021**
Install				
N	18.5 (6.7)	24.1 (7.4)	11.3 (6.3)	**0.006**
Time	2283 (924)	2761 (1583)	1249 (794)	**0.006**
Irrigate				
N	1.2 (1.3)	2.8 (2.4)	4.9 (3.7)	**0.024**
Time	34 (16)	38 (26)	55 (40)	0.670
Remove				
N	22.7 (10.4)	20.7 (8.2)	15.1 (6.8)	0.087
Time	839 (355)	666 (530)	363 (195)	**0.005**
Swab				
N	0.3 (0.7)	0.6 (1.2)	0.3 (0.9)	0.703
Time	35 (5)	61 (32)	50 (-)	0.600
X-ray				
N	0.9 (0.8)	3.0 (1.6)	3.1 (2.2)	**0.002**
Time	30 (17)	68 (25)	14 (9)	**0.000**

[a] N, mean number of actions; Time, mean duration of the action performed (seconds).
[b] statistically significant

The results show statistically significant differences between the 3 groups of surgeons for actions performed during the 2 steps. During preparation of the nose, the most experienced neurosurgeon, from Rennes, used statistically fewer gestures for holding instruments and injecting anesthetic. The neurosurgeons of both institutions statistically spent more time injecting anesthetic compared to the group of ORL ($p < 0.000$). During the approach to the dura mater, the most experienced neurosurgeon demonstrated greater economy both in time and in number of gestures for coagulating, holding and installing instruments and removing tissue. On the contrary, he spent more time and used more gestures in cutting and irrigating.

Instruments

The time taken and the number of times the instruments were used during the entire procedure are presented in **Table 4**.

TABLE 4: Mean number and duration of uses of the instruments with one or the other hand during the 2 steps[a]

Instrument	Leipzig ORL	Leipzig Neurosurgeons	Rennes Neurosurgeon	p Value
Anaesthetic				
N	1.7 (1.1)	2.0 (1.2)	1.0 (0.0)	0.075
Time	38 (23)	75 (17)	154 (38)	**0.000[b]**
Forceps				
N	19.7 (7.7)	21.7 (5.1)	11.9 (3.7)	**0.001**
Time	540 (206)	483 (206)	267 (113)	**0.001**
Tissue forceps				
N	1.9 (2.2)	0.7 (1.2)	1.3 (0.5)	0.228
Time	42 (57)	21 (42)	62 (16)	**0.021**
Bipolar forceps				
N	6.6 (3.5)	12.3 (5.2)	0.7 (1.2)	**0.000**
Time	197 (95)	289 (165)	24 (49)	**0.000**
Cup forceps				
N	11.2 (4.6)	8.2 (4.9)	9.5 (2.9)	0.453
Time	301 (121)	162 (114)	177 (68)	**0.018**
Scalpels				
N	1.1 (0.3)	1.0 (0.0)	1.2 (0.4)	0.745
Time	20 (7)	10 (2)	26 (9)	**0.000**

Scissors				
N	1.7 (2.5)	1.2 (0.5)	1.9 (0.7)	0.097
Time	23 (25)	39 (17)	17 (8)	**0.008**
Hooks				
N	1.1 (1.0)	3.0 (3.2)	1.5 (1.5)	0.299
Time	19 (16)	68 (80)	29 (33)	0.226
Retractors				
N	8.4 (2.0)	10.7 (5.1)	7.9 (4.1)	0.329
Time	612 (183)	436 (113)	384 (88)	**0.002**
Dissectors				
N	13.3 (9.4)	10.1 (2.1)	6.8 (3.4)	0.635
Time	176 (126)	160 (53)	148 (134)	0.635
Rongeurs				
N	10.9 (6.6)	11.4 (7.2)	7.2 (5.5)	0.073
Time	529 (274)	487 (531)	215 (187)	**0.004**
High-speed drill				
N	0.0 (0.0)	0.4 (0.7)	1.8 (3.1)	0.200
Time	0 (0)	14 (30)	107 (196)	0.200
Suction tube				
N	24.4 (14.2)	12.2 (4.2)	13.1 (7.1)	**0.006**
Time	2035 (878)	2585 (1538)	1322 (675)	**0.016**
Cottonoids				
N	3.4 (3.7)	4.2 (2.8)	3.2 (1.4)	0.620
Time	85 (89)	103 (103)	48 (38)	0.500
Hammer				
N	1.0 (2.3)	0.2 (0.5)	1.3 (0.9)	**0.028**
Time	28 (69)	4 (8)	30 (32)	**0.041**
Bone wax				
N	0.6 (1.3)	1.5 (1.7)	0.5 (1.1)	0.292
Time	17 (49)	31 (39)	9 (19)	0.332
Saline solution				
N	1.2 (1.3)	2.7 (2.4)	4.9 (3.7)	**0.025**
Time	19 (21)	33 (27)	55 (40)	0.087
Surgicel				
N	0.0 (0.0)	0.4 (0.7)	0.3 (0.9)	0.303
Time	0 (0)	12 (26)	4 (13)	0.209

[a] N: mean number of times the instrument was used during the surgical procedure; Time: mean time in seconds the instrument was used
[b] statistically significant

The results show statistically significant differences for the use of scissors, retractors, rongeurs, suction tube, with the neurosurgeon from Rennes demonstrating greater economy in time for using these instruments. His use of the bipolar forceps for coagulating was economical when compared with the other groups. Conversely, he used the scalpel, the tissue forceps, the hammer and the saline solution for a longer time and more frequently.

Results for the use of microscope and fluoroscopy are summarized in **Table 5**.

TABLE 5: Mean number and duration of uses of the microscope and fluoroscopy

	Leipzig ORL	Leipzig Neurosurgeons	Rennes Neurosurgeon	p Value
Microscope[a]				
N	9.6 (3.7)	12.6 (4.3)	3.5 (2.3)	**0.000**[c]
Time	2051 (843)	2537 (1555)	1119 (734)	**0.009**
Fluoroscopy[b]				
N	1.2 (1.1)	3.1 (1.4)	2.2 (1.0)	**0.008**
Time	26 (25)	64 (26)	9 (5)	**0.001**

[a] N, mean number of microscope position changes(calculated from the number of activities minus one); Time, mean length of microscope use (seconds).
[b] N, mean number of uses of fluoroscopy; Time, mean time of use of fluoroscopy (seconds).
[c] Statistically significant

The results show that the number of changes in microscope position and the time of its use were statistically lower for the most experienced neurosurgeon. Mean time of fluoroscopy use was significantly lower for this surgeon ($p< 0.001$): a similar result was demonstrated in Table 3 for the following action: X-ray ($p< 0.000$).

Anatomical structures

Times and number of gestures in intervention on the anatomical structures are presented in **Table 6**.

TABLE 6: Mean number and duration of interventions on anatomical structures in each step[a]

Anatomical Structure	Leipzig ORL	Leipzig Neurosurgeons	Rennes Neurosurgeon	p Value
Preparation nose				
Mucosa				
N	2.4 (1.4)	3.8 (2.4)	1.9 (0.3)	**0.050[b]**
Time	205 (214)	279 (108)	297 (95)	0.383
Nose				
N	0.4 (0.7)	0.5 (1.1)	0.1 (0.3)	0.457
Time	12 (38)	10 (20)	12 (38)	0.613
Approach to the dura				
Mucosa				
N	45.1 (22.0)	39.1 (15.2)	22.9 (9.0)	**0.003**
Time	1100 (253)	1366 (869)	628 (286)	**0.003**
Nasal septum				
N	6.9 (3.0)	4.3 (4.3)	6.4 (2.8)	0.301
Time	122 (36)	99 (110)	70 (33)	0.090
Sphenoid				
N	62.3 (32.1)	62.4 (24.5)	42.6 (16.6)	0.120
Time	5175 (2451)	5064 (2832)	2229 (1036)	**0.001**

[a] N, mean number of interventions on the anatomical structure in each step; Time, mean duration (seconds).
[b] Statistically significant

The results show that the Rennes neurosurgeon statistically used fewer manual gestures on the mucosa during the 2 steps. He worked a statistically shorter time on the sphenoid ($p< 0.001$) and on the mucosa ($p< 0.003$) during the approach to the dura.

Discussion

In this study, we compared the gestures of 3 groups of senior surgeons, either ORL or neurosurgeons during the transnasal transsphenoidal approach to the pituitary fossa. Although this surgical approach is a standard one and is usually performed rapidly by referent surgeons, we observed differences between these groups both in the duration and the number of gestures.

Duration

The length of the two recorded steps was seen to be shorter for the more experienced neurosurgeon (GB). During preparation of the nasal mucosa, this difference was not significant. However, during this phase duration of right hand use was equal to that of left hand use, and very significantly greater than that observed for the group of Leipzig surgeons. This result indicates that during the most stereotyped phase of the transnasal approach, the most experienced surgeon optimized the use of manual gestures by making full use of both hands: his hands did not stop working. This result was not confirmed for the other more complex phase, although time of use for each hand was seen to be shorter for this surgeon. Indeed, the Rennes surgeon spent a considerably shorter time on the approach phase than did the Leipzig surgeons.

Number of gestures

Analysis of the total number of gestures showed that the most experienced surgeon used fewer gestures than the 2 other groups during the 2 standardized phases of nasal mucosa preparation and approach of the tumor. The number was similar in the 2 groups of Leipzig surgeons, both in overall manual activity, right- or left- hand activity, in the preparation and the approach phases. The difference between Rennes and Leipzig was particularly apparent for the dominant right hand. This result appears similar to that observed in our previous study comparing senior and junior neurosurgeons during spinal surgery: the senior surgeons showed greater economy in right hand gestures during the most mechanical phase (closure).

Actions, instruments and anatomical structures

Detailed recording of gestures carried out on anatomical structures using instruments made more precise observations possible. During the nasal mucosa preparation phase, the time taken by the Rennes surgeon for injection of the anesthetic was the same as the duration of the whole phase (1/1), the surgeon being active during the entire time. The correspondence between the length of the principal gesture (injection) and length of this step of the procedure diminished with the experience of the surgeons concerned: ½ for the Leipzig neurosurgeon and ¼ for the Leipzig ORL. This result indicates increasingly economical use of time with increasing experience: greater efficiency and less waste of time during the most standardized phases.

During the approach phase, the more experienced neurosurgeon was faster and more economical than the Leipzig group of surgeons in essential manual gestures: coagulating, removing, dissecting, holding and installing (an instrument) / forceps, bipolar forceps, dissectors, retractors, rongeurs, suction tube / mucosa, sphenoid. These results seem coherent, because the differences concerned not only the principal activities carried out during the approach to the dura, but also the instruments and anatomical structures involved in this step.

The most economical use of time and gesture by the more experienced senior neurosurgeon is clearly shown in microscope use. The number of position changes was respectively 3 and 4 times greater for the groups of Leipzig ORL and neurosurgeons. Duration of use was also at least twice as long for the Leipzig surgeons. This observation confirms the results obtained concerning junior and senior neurosurgeons in spinal surgery: greater technical mastery among seniors leads to fewer and less frequent microscope position changes, which improves the fluidity of performance.[10]

Conclusions

In a previous study concerning junior and senior neurosurgeons, we demonstrated that there was a relationship between surgical practice, as determined by a method of objective measurement using observation software, and surgical experience: gesture economy evolves with seniority.[53] Using the same objective measurement, we have now compared the gesture activity of senior surgeons with different levels of expertise during another standard surgical procedure. In this first part of the study focusing on the approach to the pituitary tumor, the most stereotyped phase of the surgical procedure, we have observed that the previously established relationship between junior and senior surgeons continues to evolve with surgical experience: surgical expertise is synonymous with shorter procedures and greater efficiency in manual gesture, particularly with the dominant right hand.

Pituitary tumor surgery via transsphenoidal approach.

Part II: A study comparing tumor removal by senior neurosurgeons from different institutions, using recording of surgical processes

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KEY WORDS: Manual activity, Pituitary tumor, Surgery, Surgical workflow, Surgical process, Transsphenoidal approach

Running head: Comparison of neurosurgeons during pituitary tumor surgery

Abstract

Object.

Recording of pituitary tumor removal was carried out to ascertain whether it was possible to observe any significant differences in surgical practice between senior neurosurgeons with different professional experience.

Methods.

Thirty-four removals of pituitary tumors using transsphenoidal approach were consecutively recorded by a senior neurosurgeon. Fifteen of these were carried out by surgeons having experience of 200 procedures, and nineteen by a surgeon who had perfomed more than a thousand. Data recorded were: firstly general parameters (overall operating time and time taken for each step) and secondly general and specific aspects of the surgeon's activities (number of manual gestures, number and duration of actions performed, use of the instruments, and interventions on anatomical structures). The Mann-Whitney test was used for comparison between the 2 groups of surgeons.

Results.

In the case of the more experienced surgeon the time taken for tumor removal and hemostasis was statistically shorter. He used his left hand more frequently than the other surgeons during the whole procedure, and during reconstruction and closure. He spent less time dissecting, holding and installing instruments and removing tissue, and used fewer gestures for coagulating and dissecting.

In the other group the neurosurgeons took less time sewing and swabbing and used fewer gestures for injecting. Time of use of the microscope was also statistically shorter for the more experienced surgeon.

Conclusions.

Surgical expertise based on experience leads to shorter procedures: this efficiency is attained by increased numbers of manual gestures during more complex phases, and, possibly more significantly, by greater use of the non-dominant hand.

In the first part of the study of transsphenoidal procedures for pituitary tumors (part I), we compared senior otorhinolaryngologists and senior neurosurgeons performing transnasal routes. This approach was quite stereotyped although performed by 3 different groups of specialists in 2 different institutions. The observation of these groups demonstrated that surgical expertise is synonymous with shorter procedures and more efficient use of manual gesture.

In this second part concerning the tumor removal, we compare senior neurosurgeons with differing levels of experience. This phase is more complex and less stereotyped, and is therefore a more favorable terrain for observation of the qualities the surgeon has acquired by experience.

The same software was used to record the procedures in the two different institutions, and for the two different series of observations.[44-46,53]

Materials and Methods

Thirty-four removals of pituitary tumors using a transsphenoidal approach were recorded consecutively. Fifteen procedures were recorded in the Neurosurgery Department of the Leipzig University Hospital, Germany, between May and October 2008, and 19 procedures in the Neurosurgery Department of the Rennes University Hospital, France, between November 2008 and March 2009. The patients all presented newly diagnosed tumors.

In the Leipzig group were 6 men and 9 women with a median age of 54 years (range 16-80 years). The tumors were non-functioning pituitary macroadenomas in 12 cases and GH-secreting macroadenoma in 3 cases (suprasellar extension in 9 cases).

The Rennes group comprised 8 men and 11 women with a median age of 40 years (range 19-73 years). The tumors were non-functioning pituitary macroadenomas in 11 cases (with suprasellar extension in 8 cases), prolactinomas in 6 cases (microadenomas in 2 cases, macroadenomas in 4 cases, suprasellar extension in 1 case), GH-secreting macroadenoma in one case and ACTH-secreting tumor with Cushing's disease in one case.

Description of the participants

Tumor removal was performed in all cases by senior neurosurgeons considered as expert referent neurosurgeons for this surgical procedure in their respective institutions. Surgery involved 2 neurosurgeons in Leipzig, Germany (CT: 5 patients and JM: 10 patients), each of whom had performed about 200 of these procedures at the time of recording. In Rennes, France, surgery was carried out by only one neurosurgeon (GB) who had performed over 1000 pituitary tumor removals.

All the surgeons were right-handed.

Description of the operative procedure

The surgical approach was transnasal transsphenoidal in all cases. Positioning of the patient was different in the 2 institutions. In Leipzig, the patient was installed in the *decubitus dorsal* position, the surgeon being at the head of the table and operating from above. In Rennes, the neurosurgeon (GB) preferred to install the patient in a lawn-chair position to reduce venous pressure and bleeding. In this position, the patient's head was oriented toward the surgeon to facilitate gestures.

The procedure of tumor removal began with the dura mater incision after a common transnasal approach described in part I, and ended with the insertion of cottonoids in the nose. The surgical procedure was performed under the same type of microscope in the 2 institutions (Zeiss Pentero microscope, Carl Zeiss, Germany). The neurosurgeon in Rennes (GB) applied fat grafts in the sellar fossa and in the sphenoid in cases of cerebrospinal fluid leakage. This was not used in the Leipzig institution.

Acquisition of the surgical processes

The mode of acquisition of the data and the data structure were similar to that exposed in part I.[42-43] The ontology was also the same for this part of the procedure because the same software was used during the whole surgical process (from the preparation of the nose to the end of closure).

A screenshot of the Surgical Workflow Editor is shown in **Figure 1**.

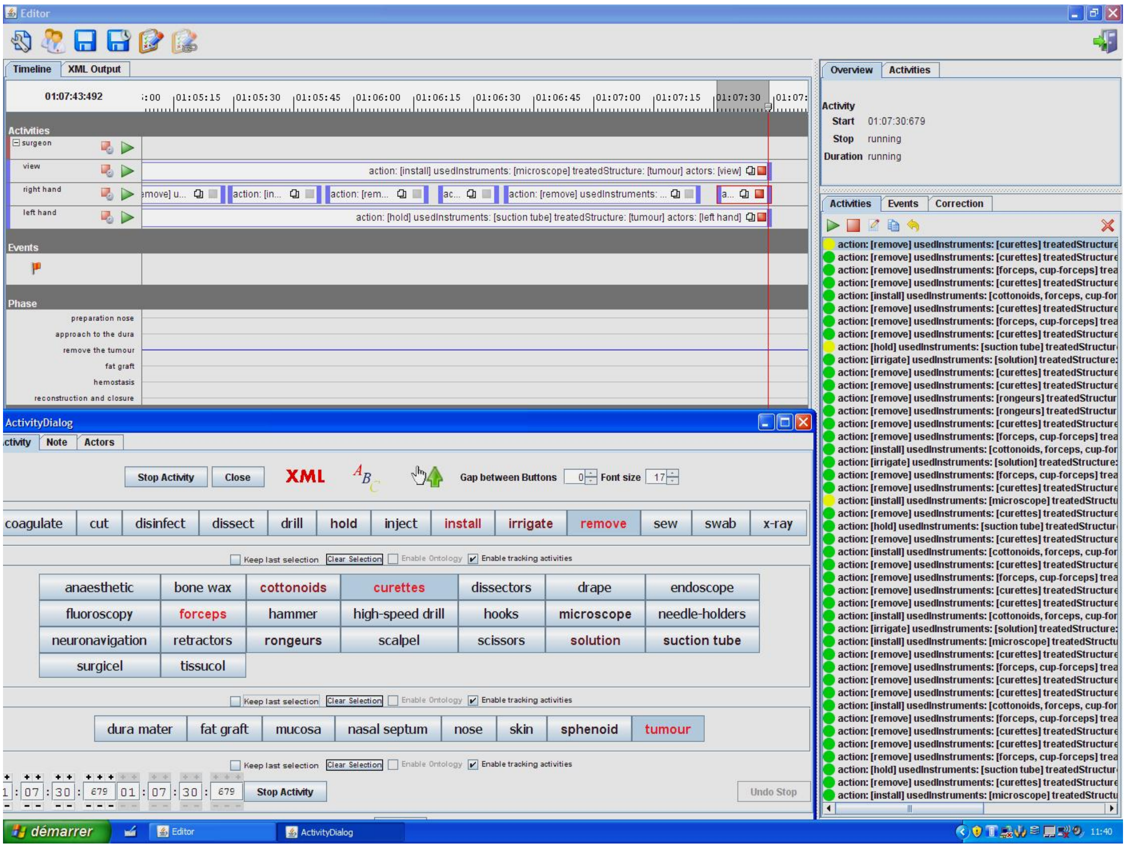

Figure 1. Screenshot of the Surgical Workflow Editor during the procedure of removal of pituitary tumor

Data recorded

As we did during the transsphenoidal approach (part I), we recorded general parameters of the surgical process, and the general and specific parameters of the surgeon's activities. General parameters of the surgical process exclusively concerned duration of the 4 different steps chosen, whereas the general and specific parameters of the surgeon's activity concerned both the cumulative duration of time and the number of activities. Recording duration of the different steps therefore took into account both time occupied by the manual activities of the surgeon, and intervals between activities.

- General parameters of the procedure: Operating time was recorded from the start of the dura mater incision to the end of cottonoid insertion into the nose. The procedure of pituitary tumor removal was divided into 4 steps: (1) tumor removal time, (2) duration of fat graft sample and insertion when appropriate (3) hemostasis, and (4) reconstruction and closure.

- General parameters of the surgeon's activity: for each step, the number of activities performed with either right or left hand, and the length of time each hand worked (total duration of manual activities), were recorded. Operating time using the operating microscope and the number of times the surgeon changed the microscope position were recorded separately as a visual activity.

- Specific parameters of the surgeon's activity: the verbs referring to the gestures were the same as for part I, as well as the instruments used and the anatomical structures treated. For the use of the operating microscope, the activity was recorded as follows: install/microscope/anatomical structure.

Analysis of data

The Mann-Whitney test was used for comparison between the 2 groups of neurosurgeons. A p value of less than 0.05 was deemed significant.

Results

Duration and number of gestures

The time taken and the number of hand movements required to perform the procedure are respectively shown in **Tables 1 and 2**.

For each step, the number of activities performed with right or left hand and the length of time each hand was active are also presented.

TABLE 1: Mean duration of whole surgical procedure and of each step according to the institution

	Mean Time in Seconds		p Value
	Leipzig Neurosurgeons (n=15)	Rennes Neurosurgeon (n=19)	
Operating time	2557 (1013)	2054 (1096)	0.089
Right hand[a]	1922 (837)	1476 (768)	0.064
Left hand[a]	2344 (936)	1767 (924)	0.052
Removal of tumor	1653 (809)	1075 (769)	**0.011**[b]
Right hand	1355 (692)	865 (617)	**0.013**
Left hand	1613 (774)	1070 (762)	**0.015**
Hemostasis	507 (215)	387 (262)	**0.050**
Right hand	298 (179)	239 (136)	0.148
Left hand	407 (212)	258 (174)	**0.019**
Fat graft insertion (n=5)[c]	-	1030 (137)	-
Right hand	-	645 (136)	-
Left hand	-	729 (156)	-
Reconstruction and closure	431 (193)	341 (164)	0.117
Right hand	288 (118)	215 110)	**0.035**
Left hand	350 (155)	234 (126)	**0.035**

[a] Mean time each hand worked during the whole procedure and in each step;
[b] Statistically significant;
[c] The step fat graft insertion concerned 5 patients

Results are mean, with standard deviations in parentheses for Table 1 to 6.

TABLE 2: Mean number of manual gestures for whole surgical procedure and for each step according to the institution

	Number of Activities Performed		p Value
	Leipzig Neurosurgeons	Rennes Neurosurgeon	
Operating time	75.5 (30.5)	73.4 (29.4)	0.811
Right hand	66.7 (28.2)	62.5 (26.3)	0.566
Left hand	6.8 (2.9)	10.9 (4.3)	**0.002**[a]
Removal of tumor	47.4 (23.5)	43.6 (23.4)	0.584
Right hand	44.7 (22.9)	41.5 (22.3)	0.554
Left hand	2.7 (1.5)	2.1 (1.7)	0.155
Hemostasis	12.8 (6.0)	10.8 (7.4)	0.157
Right hand	10.9 (5.4)	7.1 (5.1)	0.083
Left hand	1.9 (1.3)	3.7 (2.9)	0.067
Fat graft insertion (n=5)		3.7 (6.5)	
Right hand	-	2.9 (5.2)	-
Left hand	-	0.7 (1.4)	-
Reconstruction and closure	14.9 (6.5)	15.9 (7.1)	0.515
Right hand	11.2 (4.9)	11.0 (4.9)	0.952
Left hand	3.7 (2.2)	4.9 (2.6)	**0.016**

[a] Statistically significant

The results demonstrated that operating time was shorter for the more experienced neurosurgeon from Rennes but not statistically significant ($p = 0.089$). The time taken to perform each step was also shorter in Rennes: statistically shorter for tumor removal ($p < 0.011$) and hemostasis ($p < 0.050$), and shorter but not significantly so for reconstruction and closure ($p = 0.117$). The Rennes neurosurgeon carried out more gestures with the left hand than the Leipzig neurosurgeons during the whole procedure ($p < 0.002$) and during reconstruction and closure ($p < 0.016$).

Actions

The time taken and the number of actions performed by one or the other hand are presented in **Table 3**.

TABLE 3: Mean number and duration of actions performed with one or the other hand during the whole procedure[a]

Action	Leipzig Neurosurgeons	Rennes Neurosurgeon	p Value
Cut			
N	4.1 (1.7)	3.1 (2.2)	0.070
Time	123 (74)	90 (53)	0.176
Coagulate			
N	4.9 (3.4)	1.2 (1.9)	**0.000**[b]
Time	126 (76)	86 (75)	0.332
Dissect			
N	8.7 (6.1)	3.2 (3.3)	**0.000**
Time	253 (167)	63 (95)	**0.000**
Inject			
N	0.1 (0.5)	2.7 (1.1)	**0.000**
Time	26 (-)	56 (29)	0.200
Hold			
N	7.3 (3.4)	11.2 (3.8)	**0.004**
Time	2353 (939)	1672 (992)	**0.014**
Install			
N	20.7 (9.3)	25.8 (8.6)	0.093
Time	2877 (1117)	2180 (1043)	**0.040**
Irrigate			
N	3.1 (1.6)	3.1 (2.3)	0.775
Time	64 (26)	61 (51)	0.275
Remove			
N	29.1 (17.8)	26.9 (17.7)	0.804
Time	865 (565)	536 (511)	**0.017**
Sew			
N	1.2 (0.9)	2.0 (1.8)	**0.019**
Time	89 (65)	484 (134)	**0.000**
Swab			
N	1.1 (1.3)	0.9 (1.9)	0.117
Time	33 (19)	91 (60)	**0.017**

[a] N, mean number of actions during the whole surgical procedure; Time, mean duration of the action performed (seconds).
[b] Statistically significant

The results showed statistically significant differences between the 2 groups of surgeons. In Rennes, the neurosurgeon spent less time dissecting, holding and installing an instrument, and removing tissue, and used fewer gestures for coagulating and dissecting. In Leipzig, the neurosurgeons took less time sewing and swabbing and used fewer gestures for injecting.

Instruments

The time taken and the number of times instruments were used during the entire procedure are presented in **Table 4**.

TABLE 4: Mean number and duration of instrument uses with one or the other hand during whole procedure[a]

Instrument	Leipzig Neurosurgeons	Rennes Neurosurgeon	p Value
Forceps			
N	29.2 (13.7)	30.6 (14.5)	0.911
Time	817 (363)	914 (588)	0.973
Tissue forceps			
N	6.1 (6.1)	1.9 (1.7)	**0.033** [b]
Time	203 (166)	310 (377)	0.640
Bipolar forceps			
N	11.6 (7.0)	0.4 (1.0)	**0.000**
Time	330 (166)	73 (73)	**0.004**
Cup forceps			
N	11.5 (9.4)	27.3 (13.3)	**0.000**
Time	311 (289)	656 (398)	**0.003**
Monopolar forceps			
N	-	0.9 (1.8)	-
Time	-	112 (25)	-
Scalpels			
N	0.5 (0.5)	2.1 (1.0)	**0.000**
Time	11 (3)	62 (21)	**0.000**
Scissors			
N	3.7 (1.9)	0.8 (1.2)	**0.000**
Time	119 (77)	47 (21)	**0.045**
Hooks			
N	3.4 (2.9)	3.4 (2.4)	0.924
Time	134 (98)	86 (72)	0.201
Retractors			
N	2.3 (0.9)	2.5 (1.2)	0.847
Time	64 (25)	82 (31)	0.084
Dissectors			
N	7.8 (4.9)	5.1 (2.5)	0.119
Time	197 (143)	172 (94)	0.953
Rongeurs			
N	0.7 (1.4)	0.5 (1.6)	0.281
Time	103 (78)	46 (51)	0.393
Needle-holders			
N	1.2 (0.9)	2.0 (1.8)	**0.019**
Time	89 (65)	484 (134)	**0.000**
Suction tube			
N	5.3 (2.6)	5.7 (3.4)	0.856
Time	2250 (915)	1266 (874)	**0.000**
Cottonoids			
N	7.2 (3.3)	14.7 (6.4)	**0.000**
Time	195 (85)	315 (156)	**0.006**

Surgicel			
N	5.7 (3.5)	4.8 (2.7)	0.506
Time	149 (105)	164 (64)	0.187
Bone wax			
N	0.1 (0.2)	-	-
Time	41 (-)	-	-
Saline solution			
N	3.1 (1.6)	3.1 (2.3)	0.775
Time	64 (26)	61 (51)	0.275
Curettes			
N	14.3 (9.5)	16.2 (8.2)	0.289
Time	484 (356)	345 (237)	0.179
Tissucol			
N	1.3 (0.6)	2.7 (1.0)	**0.000**
Time	27 (12)	55 (25)	**0.000**

[a] N, mean number of instrument uses during the whole surgical procedure; Time, mean duration of instrument use (seconds).
[b] Statistically significant

The results first demonstrated that the Rennes neurosurgeon, statistically speaking, used the tissue forceps, bipolar forceps, scissors and suction tube with economy compared to the group of neurosurgeons in Leipzig. On the contrary, he used the scalpel, cup-forceps, cottonoids, tissucol and needle-holders for a longer time and more frequently.

Results for microscope use are summarized in Table 5.

TABLE 5: Mean number and duration of uses of the microscope during the operating time[a]

	Leipzig Neurosurgeons	Rennes Neurosurgeon	p Value
Microscope			
N	6.9 (4.0)	5.1 (3.9)	0.103
Time	2499 (1018)	1651 (928)	**0.006[b]**

[a] N, mean number of changes of microscope position during the whole surgical procedure; Time, mean time of use of microscope (seconds).
[b] Statistically significant

The results show that both the number of changes in microscope position and the duration of its use were lower for the Rennes neurosurgeon. Time of use was statistically shorter in Rennes ($p < 0.006$).

Anatomical structures

The times and number of gestures concerning intervention on the anatomical structures during the whole procedure are presented in Table 6.

TABLE 6: Mean number and duration of interventions on anatomical structures during whole surgical procedure[a]

Anatomical Structure	Leipzig Neurosurgeons	Rennes Neurourgeon	p Value
Mucosa			
N	5.4 (2.9)	2.8 (1.2)	**0.000** [b]
Time	229 (158)	88 (32)	**0.000**
Nasal septum			
N	-	1.0 (0.9)	-
Time	-	37 (25)	-
Sphenoid			
N	15.5 (7.1)	9.9 (6.5)	**0.012**
Time	3315 (1758)	668 (610)	**0.000**
Dura Mater			
N	9.7 (6.4)	3.8 (2.3)	**0.001**
Time	676 (1336)	183 (226)	**0.021**
Tumor			
N	47.7 (24.1)	52.3 (24.3)	0.589
Time	2479 (2032)	3389 (2330)	0.077
Nose			
N	2.1 (1.3)	3.0 (1.1)	**0.031**
Time	63 (42)	42 (14)	0.102
Skin			
N	-	2.6 (4.5)	-
Time	-	1213 (343)	-
Fat graft			
N	-	3.5 (6.2)	-
Time	-	459 (115)	-

[a] N, mean number of interventions on anatomical structure during whole surgical procedure; Time, mean duration (seconds).
[b] Statistically significant

The results show that the Rennes neurosurgeon statistically worked a shorter time and used fewer manual gestures on the mucosa, the sphenoid and the dura mater. However, the results were not statistically different between the 2 groups of surgeons for work on the tumor.

Discussion

In this study we have compared the gestures of 2 groups of senior neurosurgeons accustomed to performing removal of pituitary tumors using the transsphenoidal approach, and considered as experts in this pathology in their respective institutions. We have defined and described the differences between these 2 groups both in the duration and the number of gestures.

Duration

Average overall time for the surgical procedure was seen to be shorter in the case of the most experienced neurosurgeon (GB) although this result was not statistically significant ($p = 0.089$). In fact, the time necessary for the fat graft insertion used to prevent CSF leakage in Rennes probably contributed to an underestimation of the difference in overall length of procedure between the 2 groups, even though this step was only carried out in 5 cases out of 19 (26%). In fact, all other steps in the procedure took shorter times when performed by the most experienced surgeon. Difference observed in the length of the final step (reconstruction and closure) was not statistically significant, probably because this is shorter, technically easier and more stereotyped.

Number of gestures

Recording of the number of manual gestures during the whole procedure and during each separate phase indicated at least 2 strikingly convergent results. The first was that the average number of right-hand activities did not differ between the 2 groups of right-handed surgeons, in spite of shorter procedure durations (overall or phase by phase) for the most experienced neurosurgeon. Therefore in a given length of time, the experienced surgeon carried out a greater number of right-hand gestures than his colleagues. Secondly, the average number of left-hand gestures was also greater for the experienced surgeon although overall procedure time was shorter. In short, the senior surgeon used more gestures, with both hands, than his colleagues in a similar more complex procedure. This may mean that in a group of senior surgeons expertise or intensive specialization leads to optimization of surgical activity both by reducing overall procedure times and by increasing the number of gestures performed by both hands, possibly even more significantly those by the non-dominant hand.

Actions, instruments and anatomical structures

More detailed recording of actions performed, instruments used and anatomical structures involved during the surgical procedure enabled us to assess the surgeons' manual activity and proceed to a comparison of the 2 groups. The senior surgeon was seen to save time in preparing and carrying out tumor removal (dissecting, holding an instrument, removing tissue / scissors, hooks, dissectors, curettes, suction tube / mucosa, sphenoid, dura mater) and hemostasis (coagulating, bipolar forceps). Differences observed between the 2 groups for monopolar forceps, scalpels, needle-holders, cottonoids, tissucol / sewing, swabbing, injecting / skin could be explained by the fact that they principally concerned the phase of fat graft sampling and insertion carried out by the Rennes neurosurgeon when CSF leakage occurred.

Another important point demonstrated by these recordings concerned microscope use. The most experienced neurosurgeon used this instrument more economically both in terms of duration and of position changes. Length of microscope use was statistically shorter for the senior surgeon and position changes were less frequent although the difference was not statistically significant. Similar results were obtained in a previous study comparing senior and junior neurosurgeons, the former optimizing their use of the instrument and thus achieving a greater fluidity in the procedure.[53]

Nonetheless, it is not easy to give a definitive interpretation of the differences observed between 2 groups of surgeons working in 2 institutions in different countries. We may wonder whether they really represent a different level of expertise or whether they simply reflect differing surgical practice in the two countries (different schools of thought). The considerable difference in practical experience of this procedure between the 2 groups (1000 operations versus 200), the similar context (same types of patient, equipment, institution) and the pertinence of the results obtained arguing an increasing optimization of gesture through experience (simultaneous reduction in duration of gesture and increase in number of some specific manual activities) suggest that results reflect a difference in experience. The effect of differing schools of thought cannot however be totally excluded, and study of recordings of other surgical procedures should allow a better definition of this aspect.

Conclusions

In the first part of the study concerning the transnasal transsphenoidal approach to pituitary tumors (part I), we demonstrated that surgical expertise founded on experience is synonymous with shorter procedures and greater efficiency in manual gesture.

In this second part of the study focused on tumor removal, we observed that the relationship previously established between the performance of surgeons during the stereotyped phases evolves during more complex phases: greater surgical experience is also synonymous with a more intense manual activity level, involving a greater use of the non-dominant hand.

CONCLUSION

Conclusion

The objective measure and analysis of the manual activity of surgeons in real-life operating situations can serve several purposes. The most obvious ones are the assessment of the operator's skills, and the analysis of the learning process.

- The need for objective skills analysis is a recent preoccupation, and the main studies have so far sought the best method of assessment.[14] Aggarwal et Darzi[3] acknowledged that analysing the operating skills of a given individual necessitated fragmenting the procedure under study, observing it and comparing it with a similar procedure performed by an expert. Assessment of the manual skills of a surgeon is therefore necessarily carried out in a real-life situation, and objective evaluation involves comparison with the performance of an expert. Using the SWE enables us as of now to provide objective, and no longer subjective, analyses of gestual skills in real-life situations.

- Earlier in the process, previous to assessment, recording of surgical procedures may enable us to judge a junior surgeon's skill acquisition in a particular gesture, an activity, a step or an entire procedure, and assess his learning curve. SWE thus becomes a teaching tool making it possible to assess skills or to have your skills assessed in order to improve them, in an objective manner, and no longer subjectively. In one of our studies, for example, we demonstrated that junior surgeons have too often recourse to the operating microscope, which is potentially harmful to the fluidity of the gesture being performed, and may disturb the flow of the procedure and reduce its efficiency. The concrete results of this study of the manual activity of junior surgeons using this program in real-life situations thus enables us to identify the weak point in their skills and quantify it, thus allowing us to advise them how to correct it. Learning of surgical gestures should therefore include an assessment: an assessment which leads to correcting errors, and to progressing.

- At a more theoretical level, that preceding the assessment and acquisition of technical gestures, the recording of procedures carried out by senior surgeons facilitate the understanding of surgical logic and know-how, in other words it enables us to establish the theoretical basis of knowledge which today remains essentially implicit and intuitive. The following step is therefore formal and explicit analysis and description of surgical knowledge: better understanding the process so as better to learn, to assimilate and to improve it.[26] Once recorded, the process can be analyzed, divided into stages and sub-stages, and classified. Analysis of the performance of the procedure and its different stages then allows understanding of the gestures performed, their number and how they follow on one from the other, the instruments used, the sequence of their use and possible repetitions, the key structures encountered; in short, this analysis makes it possible to develop a model of the procedure. Modeling the surgical stages and their succession enables us to identify and extract the invariables and the variable information for each procedure, to predict the surgical scenarios and to define generic models which will then serve as prototypes for the junior surgeon during his training.

These studies thus illustrate the relationship in surgical practice between the surgeon's experience and the manual skills demonstrated in real-life situations. This allows us to assert that there exists a real optimization of surgical gestures which develops with the seniority of the surgeon:

- **overall reduction of operating time,**
- **reduction of the number of gestures in the most standardized phases particularly with the dominant hand,**
- **optimization of non-dominant hand use in the most complex phases**.

These are encouraging results which should be confirmed in other surgical models or other medical fields which require manual experience.

Using an objective measuring system should make it possible to define a standard of performance for a given procedure, when carried out in similar conditions. This standard could be used to assess manual skills, and in the training of surgical students. It thus represents an essential first step towards the creation of tools to assist the training of junior surgeons by allowing them to assess their performance in comparison with that of more experienced surgeons.

Study Perspectives

1) Two standard surgical procedures (removal of lumbar and cervical disc herniation) will be studied with a dual purpose:

- establishing whether there exist differences comparable to those already observed between the recordings of these 2 procedures performed by senior neurosurgeons from Rennes and Leipzig with differing professional experience

- determining whether there exist differences in the succession of manual gestures carried out by the neurosurgeons of the different hospitals according to the « dynamic time warping » method developed in our laboratory.[18]

The purpose is to progress further in the analysis of the surgical process, and attempt to define how surgeons progress towards expertise, in other words what separates a senior surgeon from an expert surgeon.

2) Recording over several years, for future study, of removal of pituitary tumor and cervical disc herniation procedures carried out by the same senior neurosurgeon since the beginning of his neurosurgical qualification began in May 2011. This will make it possible to analyse the learning curve of his manual activities: how is he progressing? In which phases of the process? At what point in his experience is he progressing?

Further studies remain necessary before it is possible to begin to apprehend the complexity of the surgical process, of learning and of expertise in this field.

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Enregistrement des procédures chirurgicales crâniennes et rachidiennes, et analyse des « workflows » pour l'étude du processus chirurgical.

Résumé en français

Introduction

Comprendre le processus chirurgical, c'est à dire comprendre le processus d'apprentissage du geste à réaliser, sa préparation, son exécution et enfin son optimisation est un projet ambitieux. Depuis de nombreuses années, aux laboratoires de l'université de Rennes IDM UPRES EA 3192 puis VisAGeS U746 et maintenant MediCIS U1099 LTSI ont été menés de nombreux travaux pour essayer de définir des outils ou des stratégies permettant d'aider le processus de préparation de la procédure chirurgicale[23,24] mais aussi d'approcher et d'appréhender la compréhension de sa réalisation.[25,26,39,50]

Depuis 2008, nous avons mené une collaboration étroite avec l'Innovation Center Computer Assisted Surgery (ICCAS) de l'Université de Leipzig en Allemagne et donné un nouvel élan dans cette approche de la compréhension du processus de réalisation du geste chirurgical. Cet élan a été possible grâce à un séjour de 6 mois à ICCAS, Leipzig, et grâce à l'aide de Thomas Neumuth, PhD, maintenant directeur scientifique du « Model-based Automation and Integration » à ICCAS. C'est en effet grâce à son outil, le Surgical Worflow Editor (SWE),[42,43] qu'ont été possibles les travaux présentés dans cette thèse. Cet outil est programme informatique qui permet d'enregistrer en live ou vidéo toute l'activité gestuelle d'une ou plusieurs parties du corps d'une ou plusieurs personnes sous la forme d'un triplet action-instrument-cible.[44-46,53] C'est également aussi grâce à l'accueil de toute l'équipe d'ICCAS et à celui des chirurgiens du service de neurochirurgie de l'Hôpital Universitaire de Leipzig que ce travail a été possible.

Nous avons souhaité évoluer en plusieurs étapes. Après la reconnaissance du SWE et de sa validation,[44] il a été alors possible de justifier le travail entrepris par l'outil reconnu, d'analyser les données enregistrées et de les interpréter. Le déroulé de la stratégie des travaux à faire dépendait de cette reconnaissance. Nous avons choisi d'étudier des procédures chirurgicales « simples », c'est-à-dire des procédures fréquentes, standardisées et de courte durée. Nous avons donc enregistré en direct au bloc opératoire du service de Neurochirurgie de l'Hôpital Universitaire de Leipzig l'activité gestuelle des chirurgiens réalisant des procédures chirurgicales rachidienne (exérèse d'hernies discales lombaires) et crânienne (exérèse d'adénomes hypophysaires par voie transsphénoïdale), puis de la même façon, ces procédures ont été enregistrées dans le service de Neurochirurgie de l'Hôpital Universitaire de Rennes.

A partir des données accumulées, il était alors possible d'étudier plusieurs axes : comparer l'activité gestuelle des chirurgiens juniors et seniors au cours de la même procédure ou bien comparer les activités des chirurgiens seniors en fonction de leur expérience. Une autre stratégie aurait pu être aussi de comparer les activités gestuelles des chirurgiens des 2 institutions mais c'est un travail délicat car d'interprétation difficile.

Nous avons donc rassemblé dans cette thèse les 3 premiers travaux originaux issus des enregistrements des procédures chirurgicales crânienne (exérèse d'adénomes hypophysaires par voie transsphénoïdale) et rachidienne (exérèse d'hernies discales lombaires) réalisées dans les services de Neurochirurgie de Leipzig et Rennes.

Enregistrement des procédures chirurgicales : étude comparant des neurochirurgiens seniors et juniors lors de la chirurgie d'exérèse de hernies discales lombaires

Contexte : Evaluer la pratique chirurgicale en direct au bloc opératoire est difficile et son appréciation est largement subjective.

Objectif de l'étude : Des enregistrements de procédures chirurgicales standardisées rachidiennes ont été réalisés pour déterminer si des différences significatives de pratique chirurgicale pourraient être observées entre neurochirurgiens seniors et juniors.

Matériels et méthodes : Vingt quatre procédures de discectomies lombaires ont été consécutivement enregistrées par un neurochirurgien senior au bloc opératoire du service de neurochirurgie de l'hôpital universitaire de Leipzig en Allemagne, entre juin et octobre 2008. Aucun des patients n'avait été opéré auparavant du rachis, tous les chirurgiens étaient droitiers. Dans 12 cas, la chirurgie a été entièrement accomplie par un neurochirurgien senior avec l'aide d'un interne. Dans les 12 autres cas, la chirurgie a été réalisée par un interne avec l'aide d'un neurochirurgien senior. Cinq neurochirurgiens seniors ayant accompli plus de 100 fois cette procédure et 5 internes différents (2 internes en 3° année d'internat et 3 internes en 7° année) ont été observés. Les données enregistrées étaient (1) des paramètres généraux : temps opératoire pour l'ensemble de la procédure ou pour chacune des étapes prédéfinies (approche du disque intervertébral, discectomie, hémostase, fermeture) ; (2) des paramètres généraux de l'activité gestuelle du chirurgien : nombre d'activités réalisées par la main droite ou la main gauche, temps de travail de l'une ou l'autre main, temps global de l'activité gestuelle. Le temps d'utilisation du microscope opératoire a été enregistré séparément comme une activité visuelle ainsi que la durée d'utilisation de la scopie à rayons X ; (3) des paramètres spécifiques de l'activité gestuelle du chirurgien : toutes les actions accomplies par la main droite ou gauche ont été enregistrées séparément sous la forme d'un triplet action-instrument-cible anatomique. L'action était définie par un verbe : coaguler, couper, disséquer, fraiser, tenir, installer, irriguer, enlever, suturer,

tamponner ; les instruments étaient les suivants : bistouri, ciseaux, dissecteurs, écarteurs, pinces (pince classique à préhension, pince à disque, pince bipolaire, pince monopolaire), rongeurs, crochets, fraise à haute vitesse, suceurs, porte-aiguilles, cotons, cire hémostatique, solution de rinçage ; les cibles anatomiques étaient divisées en peau, fascia, muscle, ligament, disque, racine nerveuse, dure-mère, vertèbre. Le test statistique de Mann-Whitney a été utilisé pour la comparaison des 2 groupes de chirurgiens avec une valeur p inférieure à 0,05 considérée comme significative.

Résultats : Le temps opératoire pour l'ensemble de la procédure était statistiquement plus court dans le groupe des neurochirurgiens seniors ($p<0,039$). Les seniors ont démontré de façon statistiquement significative une plus grande économie de temps ($p<0,006$) et de gestes ($p<0,031$) pendant la phase de fermeture. La main droite des chirurgiens seniors a travaillé moins longtemps ($p<0,039$) et leur main gauche a fait moins d'activités ($p<0,016$) pendant cette phase. Nous avons observé des différences significatives pour l'action de suturer : les chirurgiens seniors réalisant moins longtemps ($<0,024$) et moins souvent ($p<0,014$) cette action. Nous avons également observé des différences dans le temps d'utilisation et le nombre de gestes avec les instruments suivants : ciseaux, porte-aiguilles et pinces, dans le sens d'une plus grande économie pour les chirurgiens seniors. Le nombre de changements de position du microscope était également moins important dans ce groupe de chirurgiens ($p<0,019$) alors que le temps d'utilisation n'était pas statistiquement différent. Enfin, les chirurgiens seniors ont statistiquement travaillé moins longtemps sur la peau ($p<0,001$) et ont fait moins de gestes sur le fascia thoraco-lombaire ($p<0,006$).

Conclusions : Cette étude basée une méthode objective d'enregistrement en temps réel, illustre la relation qui existe entre la pratique chirurgicale au bloc opératoire et l'expérience chirurgicale. Il a été ainsi possible de montrer que l'économie des gestes réalisés au cours de la procédure évolue avec la seniorisation. L'utilisation de cette méthode objective de mesure pourrait permettre d'établir un standard de performance pour une procédure donnée dans une certaine condition. Ce standard pourrait être utilisé à la fois dans l'évaluation de la dextérité manuelle et dans l'entrainement des chirurgiens les plus jeunes.

Chirurgie d'exérèse des adénomes hypophysaires par voie transsphénoïdale.
Partie I : étude comparant les otorhinolaryngologistes et les neurochirurgiens réalisant la voie d'abord transnasale, par une méthode d'enregistrement de la procédure chirurgicale

Objectif de l'étude : Des enregistrements de procédures chirurgicales de voie d'abord transsphénoïdale-transnasale pour des tumeurs hypophysaires ont été réalisés pour déterminer si des différences significatives de pratique chirurgicale pourraient être observées entre otorhinolaryngologistes (ORL) et neurochirurgiens seniors.

Matériels et méthodes : Vingt sept procédures d'abord transsphénoïdale de tumeurs hypophysaires ont été consécutivement enregistrées par un neurochirurgien senior au bloc opératoire des services de neurochirurgie des hôpitaux universitaires de Leipzig et de Rennes, entre mai 2008 et janvier 2009. La voie d'abord transsphénoïdale-transnasale a été réalisée par 3 ORL seniors dans 9 cas (Leipzig), par un neurochirurgien senior ayant l'expérience de 200 procédures dans 8 cas (Leipzig) et par un neurochirurgien ayant l'expérience de plus de 1000 procédures dans 10 cas (Rennes). Aucun des patients n'avait été opéré auparavant par cette voie, les chirurgiens étaient tous droitiers. Les données enregistrées étaient (1) des paramètres généraux : temps opératoire pour l'ensemble de la procédure ou pour chacune des étapes prédéfinies (préparation du nez et approche de la dure-mère) ; (2) des paramètres généraux de l'activité gestuelle des chirurgiens : nombre d'activités réalisées par la main droite ou la main gauche, temps de travail de l'une ou l'autre main, temps global de l'activité gestuelle. Le temps d'utilisation du microscope opératoire a été enregistré séparément comme une activité visuelle ainsi que la durée d'utilisation de la scopie à rayons X ; (3) des paramètres spécifiques de l'activité gestuelle du chirurgien : toutes les actions accomplies par la main droite ou gauche ont été enregistrées séparément sous la forme d'un triplet action-instrument-cible anatomique. L'action était définie par un verbe :

coaguler, couper, disséquer, fraiser, tenir, injecter, installer, irriguer, enlever, suturer, tamponner, irradier ; les instruments étaient les suivants : anesthésique, bistouri, ciseaux, marteau, dissecteurs, pinces (pince classique à préhension, pince à tumeur, pince bipolaire), écarteurs, rongeurs, crochets, porte-aiguilles, fraise à haute vitesse, suceurs, cotons, cire hémostatique, solution de rinçage, tissucol ; les cibles anatomiques étaient divisées en nez, muqueuse, septum nasal, os sphénoïde, dure-mère. Le test statistique de Kruskal-Wallis a été utilisé pour la comparaison des 3 groupes de chirurgiens avec une valeur p inférieure à 0,05 considérée comme significative.

Résultats : Le temps opératoire pour réaliser la voie d'abord jusqu'à la dure-mère était statistiquement plus court pour le neurochirurgien le plus expérimenté de Rennes ($p<0{,}010$). Celui-ci a également utilisé moins longtemps ($p<0{,}004$) et moins souvent ($p<0{,}027$) sa main droite pendant cette phase d'abord, et a globalement réalisé moins de gestes pour les 2 phases. Nous avons observé des différences significatives pendant la phase de préparation du nez : le chirurgien le plus expérimenté a statistiquement faits moins de gestes pour les actions de tenir un instrument et injecter l'anesthésique. Les neurochirurgiens des 2 institutions ont aussi passé moins de temps que les ORL pour injecter l'anesthésique ($p<0{,}000$). Pendant la phase d'approche de la dure-mère, le chirurgien le plus expérimenté a démontré une plus grande économie de temps et de nombre de gestes pour coaguler, tenir et installer des instruments, et enlever du tissu. Au contraire, il a passé plus de temps et réalisé plus souvent les actions de couper et irriguer. Nous avons également observé des différences dans le temps d'utilisation avec les instruments suivants : ciseaux, écarteurs, suceurs, pince bipolaire dans le sens d'une plus grande économie pour le chirurgien de Rennes. Au contraire, il a utilisé plus longtemps et plus souvent le bistouri, les pinces à préhension, le marteau et la solution de rinçage. Le nombre de changement de position du microscope et son temps d'utilisation étaient aussi statistiquement moins élevés que pour les autres chirurgiens. Enfin, ce chirurgien expert a réalisé moins de gestes sur la muqueuse et l'os sphénoïde.

Conclusions : En utilisant la même méthode objective d'enregistrement en temps réel que dans l'étude précédente, nous avons maintenant comparé l'activité gestuelle de chirurgiens seniors ayant différents niveaux d'expérience pendant une autre procédure chirurgicale standardisée. Dans cette première partie de la procédure concernant la phase la plus stéréotypée c'est-à-dire la voie d'abord transphénoïdale-transnasale, nous avons observé que la relation précédemment établie entre chirurgiens juniors et seniors continuait d'évoluer chez les seniors avec le niveau d'expérience chirurgicale : l'expertise chirurgicale est synonyme de temps opératoires plus courts et d'une plus grande efficacité gestuelle en particulier avec la main droite dominante.

Chirurgie d'exérèse des adénomes hypophysaires par voie transsphénoïdale.
Partie II : étude comparant des neurochirurgiens seniors d'institutions différentes réalisant l'exérèse tumorale, par une méthode d'enregistrement de la procédure chirurgicale

Objectif de l'étude : Des enregistrements de procédures chirurgicales d'exérèse de tumeurs hypophysaires ont été réalisés pour déterminer si des différences significatives de pratique chirurgicale pourraient être observées entre neurochirurgiens seniors d'expériences professionnelles différentes.

Matériels et méthodes : Trente quatre procédures d'exérèse de tumeurs hypophysaires après une voie d'abord transsphénoïdale ont été consécutivement enregistrées par un neurochirurgien senior au bloc opératoire des services de neurochirurgie des hôpitaux universitaires de Leipzig et de Rennes, entre mai 2008 et mars 2009. Quinze procédures ont été accomplies par 2 neurochirurgiens de Leipzig ayant l'expérience de 200 procédures et 19 ont été faites par un neurochirurgien à Rennes ayant l'expérience de plus de 1000 tumeurs hypophysaires. Tous les chirurgiens étaient droitiers. A Leipzig, il s'agissait de macroadénomes non fonctionnels dans 12 cas et de macroadénomes à GH dans 3 cas (extension suprasellaire dans 9 cas). A Rennes, il s'agissait de macroadénomes non fonctionnels dans 11 cas (extension suprasellaire, 8 cas), de microprolactinomes dans 2 cas, de macro-prolactinomes dans 4 cas (extension suprasellaire, 1 cas), d'un macroadénome à GH et d'un adénome à ACTH avec maladie de Cushing. Les données enregistrées étaient (1) des paramètres généraux : temps opératoire pour l'ensemble de la procédure ou pour chacune des 4 étapes prédéfinies (exérèse de la tumeur, prélèvement et insertion d'un greffon graisseux si nécessaire, hémostase, reconstruction et fermeture) ; (2 et 3) des paramètres généraux et spécifiques de l'activité gestuelle des chirurgiens identiques à ceux de la première partie Le test statistique de Mann-Whitney a été utilisé pour la comparaison des 2 groupes de chirurgiens avec une valeur p inférieure à 0,05 considérée comme significative.

Résultats : Le temps opératoire pour réaliser toute la procédure était plus court pour le neurochirurgien le plus expérimenté à Rennes sans être toutefois significatif (p=0,089). Tous les temps des différentes phases étaient plus courts pour ce chirurgien : significativement pour réaliser l'exérèse tumorale (p<0,011) et l'hémostase (p<0,050), sans différence significative pour la phase de reconstruction et fermeture. Le neurochirurgien de Rennes a également réalisé plus de gestes avec la main gauche que les neurochirurgiens de Leipzig pendant toute la procédure (p<0,002) et pendant la phase de reconstruction et fermeture (p<0,016). Nous avons observé des différences significatives entre les 2 groupes pour réaliser les actions de disséquer, tenir et installer des instruments, enlever (moins de temps pour le chirurgien de Rennes), coaguler et disséquer (moins de gestes), suturer et tamponner (moins de temps pour les chirurgiens de Leipzig) et injecter (moins de gestes pour ces derniers). Nous avons également observé des différences dans le temps d'utilisation avec les instruments suivants : ciseaux, suceurs, pinces bipolaire et à préhension dans le sens d'une plus grande économie pour le chirurgien de Rennes. Au contraire, il a utilisé plus longtemps et plus souvent le bistouri, les pinces à tumeur, les cotons, le tissucol et les porte-aiguilles. Le nombre de changement de position du microscope et son temps d'utilisation étaient aussi moins élevés que pour les autres chirurgiens (temps plus court p<0,006). Enfin, le neurochirurgien le plus expérimenté a statistiquement travaillé moins longtemps et moins souvent sur la muqueuse, l'os sphénoïde et la dure-mère. Nous n'avons pas observé de différences pour la tumeur.

Conclusions : Dans la première partie de l'étude de cette procédure concernant la voie d'abord transsphénoïdale transnasale, nous avons démontré que l'expertise chirurgicale basée sur l'expérience était synonyme de temps opératoire plus court et d'une plus grande efficacité gestuelle. Dans cette deuxième partie de l'étude ciblée sur le temps d'exérèse tumorale, nous avons observé que la relation précédemment établie entre les chirurgiens pendant les phases stéréotypées évoluait pendant les phases plus complexes : l'expérience chirurgicale plus grande est synonyme d'une activité manuelle plus intense particulièrement avec la main non dominante.

Conclusion

La mesure objective et l'analyse de l'activité gestuelle des chirurgiens dans un contexte réel ont plusieurs finalités. Celles qui nous apparaissent les plus évidentes concernent l'évaluation des compétences de l'opérateur et l'appréciation de l'apprentissage.

- Le besoin d'évaluer les compétences de façon objective est une préoccupation récente, et les principaux travaux ont jusqu'à maintenant cherché la meilleure façon d'évaluer ces compétences ont reconnu que pour évaluer les compétences d'un opérateur, il était nécessaire de fragmenter la procédure à étudier, l'observer et la comparer avec une même procédure réalisée par un expert.[3,14] L'appréciation de la compétence manuelle d'un chirurgien passe donc par sa mise en situation réelle et son évaluation objective par rapport à une pratique d'expert. L'utilisation du SWE nous donne l'opportunité de proposer dorénavant une évaluation objective et non plus subjective de la performance gestuelle en situation réelle.

- Plus en amont, c'est-à-dire avant l'évaluation, l'enregistrement des procédures chirurgicales peut permettre d'apprécier l'apprentissage par un chirurgien junior d'un geste, d'une activité, d'une étape ou de la procédure en entier, et d'évaluer sa courbe de progression. L'outil SWE devient alors un outil pédagogique permettant de s'évaluer ou de se faire évaluer afin de se corriger, de façon objective et non plus subjective. Dans l'une de nos études, nous avons par exemple montré que les chirurgiens juniors mobilisaient trop souvent le microscope opératoire, ce qui pouvait nuire à la fluidité du geste en cours de réalisation, donc perturber son déroulé et diminuer ainsi son efficacité. Le retour concret de l'expertise de l'activité gestuelle des juniors avec cet instrument en conditions réelles a donc permis d'identifier le point faible de leur activité, de le quantifier pour le restituer et finalement leur conseiller comment le corriger. L'apprentissage de la gestuelle chirurgicale nécessite donc une évaluation : évaluer pour corriger et progresser.

- A un niveau de réflexion plus théorique, en amont de l'évaluation et de l'apprentissage du geste technique, l'enregistrement des procédures réalisées par les chirurgiens seniors permet aussi de comprendre la logique et le savoir-faire chirurgical, c'est-à-dire qu'il permet de donner la base d'une connaissance aujourd'hui principalement implicite et intuitive. La démarche devient alors de rendre explicite et formelle la connaissance chirurgicale : mieux comprendre le processus pour mieux l'apprendre, l'assimiler et l'améliorer. Une fois enregistrée, la procédure peut être décortiquée, divisée en étapes et sous-étapes et classée. L'analyse du déroulé de la procédure et de ses étapes permet alors de comprendre les activités effectuées, leurs nombres et leurs enchainements, les instruments utilisés, la séquence de leur utilisation et les répétitions éventuelles, les structures clé rencontrées, en résumé cette analyse permet de modéliser la procédure. La modélisation des étapes chirurgicales et de leur enchainement permet au final d'identifier et d'extraire les invariants et les informations variables pour chaque procédure, de prédire des scenarii chirurgicaux, d'établir des modèles génériques qui serviront ainsi de prototypes au chirurgien junior lors de son apprentissage.

Ces travaux illustrent donc les relations existant dans la pratique chirurgicale entre l'expérience des chirurgiens et la technique gestuelle dans un contexte de chirurgie réelle. Cela nous permet d'établir qu'il existe une réelle optimisation gestuelle évoluant avec la seniorisation des chirurgiens :

- **économie globale du temps d'intervention**
- **économie du nombre de gestes dans les phases les plus stéréotypées particulièrement avec la main dominante**
- **optimisation de la main non dominante dans les phases les plus complexes.**

Ces résultats sont encourageants et devraient être confirmés dans d'autres modèles chirurgicaux ou d'autres champs de la médecine qui requièrent une expérience manuelle.

L’utilisation d’un système de mesure objectif pourrait permettre de définir un standard de performances pour une procédure donnée, à réaliser dans des conditions semblables. Ce standard pourrait être utilisé pour l’évaluation des performances manuelles et dans l’entraînement des chirurgiens en formation. Il constitue ainsi un premier pas essentiel à la création de systèmes d’aide à l’éducation des chirurgiens juniors en permettant de s’évaluer par rapport aux chirurgiens plus expérimentés.

Travaux à venir et perspectives

1°) Deux procédures chirurgicales standardisées (exérèse d'hernies discales lombaires et cervicales) seront également étudiées dans un double but :

- chercher s'il existe des différences comparables à celles déjà observées entre les enregistrements de ces 2 procédures chirurgicales réalisées par des neurochirurgiens seniors de Leipzig et de Rennes mais n'ayant pas la même expérience chirurgicale (jeune chirurgien senior versus expert),

- déterminer s'il existe des différences dans l'enchainement des activités gestuelles des neurochirurgiens des 2 sites selon la méthode du « dynamic time warping » développée dans notre laboratoire.[18]

Le but est d'aller encore plus loin dans l'analyse du processus chirurgical, d'essayer de définir comment progressent les chirurgiens vers l'expertise, autrement dit qu'est ce qui différencie un jeune chirurgien senior et un chirurgien expert.

2°) L'enregistrement de façon prospective pendant plusieurs années de 2 procédures chirurgicales (exérèse d'hernies discales lombaires et exérèse d'adénomes hypophysaires par voie transsphénoïdale) réalisées par un jeune neurochirurgien senior depuis le début de sa qualification neurochirurgicale. Ce travail a débuté en mai 2011 et la finalité est d'analyser sa courbe de progression des activités gestuelles : comment progresse-t-il ? Dans quelle phase progresse-t-il ? A quel moment de son expérience progresse-t-il ? …

De nombreux travaux restent cependant encore à faire avant de pouvoir commencer à comprendre l'élaboration du processus chirurgical, son apprentissage et son expertise.

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